Late Jurassic Plants from the Somanakamura Group in the Outer Zone of Northeast Japan

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for the Degree of Doctor of Philosophy in Science

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Contents

Abstract

This study deals with the plant macrofossils from the Upper Jurassic Tochikubo and Tomizawa formations, Somanakamura Group in the Outer Zone, Northeast Japan. The Middle Jurassic to lowermost Cretaceous Somanakamura Group crops out in a narrow zone along the eastern margin of the Abukuma Mountains. The Somanakamaura Group is subdivided into six formations. Among which the Tochikubo Formation, the middle of this group, has been well known to occur abundant plant fossils. Since 1996, local collectors have provided plant fossils for my study. More recently, two thousands of plant fossils were found from the Tochikubo and Tomizawa formations during the construction of the Joban Highway.

By careful observation of about 3,000 plant fossils, 58 species belong to 31 genera were recognized from the Tochikubo and Tomizawa formations. Ferns are the most abundant group in the flora. The ultimate pinnules of the ferns, such as common species *Eboracia microlobifolia* (525 specimens), are rather small compared with ferns of other Mesozoic ferns in Japan. *Matonidium* ex gr. *M. goepperti* has close affinities to extant plant taxa Matoniaceae. Bennettitales are abundant in the collection. More than 500 leaf and reproductive organ fragments belong to Bennettitales. Especially, *Zamites* and *Ptilophyllum* are very common. The most common frond of Cycadales is *Nilssonia.* About 200 specimens from the five localities belong to *Nilssonia schaumbergensis. Nilssonia* of broad leaf; *N. Canadensis, N. densinervis* and others are also common. Conifers are rare in the flora. The most common leaves are *Parasequoia* sp. cf. *P. cretacea. Parasequoia cretacea* was reported from the Lower Cretaceoous of Southern Primorye. The common elements in the Inner Zone of Japan; ginkgpalean, czekanowskialean, Podozamites, etc. have not been found.

A close affinity has been indicated in Jurassic sedimentation occurs between the South Kitakami Mountains and the Soma Area, along the eastern margin of the Abukuma Mountains. The radiolarian and ammonite assemblages of both areas exclusively comprise elements of the Tethyan and Pacific biogeographic provinces of lower to middle latitudes. Therefore, I tried to compare the floras of the South Kitakami and the Soma areas.

Seventeen species among the 100 species of fossil plants are common between the South Kitakami and the Soma area. The plant-assemblage from the Somanakamura has something in common with those of South Kitakami because of the large number of the localities and specimens of the common species. The numbers of common species' specimen comprise about sixty percent of all the specimens.

The followings are concluding remarks of this study

(1) The Soma Flora

From the above plant assemblage, I concluded that the Late Jurassic flora from the Somanakamura Group belongs to the Ryoseki-type flora. Several new elements; *Neocalamites*, *Nilssoniocladus*, *Encephalartites*, *Pelourdea* were recorded in the Ryoseki-type flora by this study.

(2) Paleoenvironment presumed by fossil plants

The plant assemblage of the Soma Flora indicate tropical climate with long arid season. The existence of Matoniaceae and large sized tree ferns indicate tropical climate. The Leaves of *Nilssonia schaumbergensis* and *Sagenopteris* sp. have abscission layers at the base of the petiole. This character indicates seasonality and might point an arid season.

(3) Comparison with the floras in the South Kitakami Belt

As a proved result, the Late Jurassic floras from the Somanakamura, Oshika and Shishiori groups have now many features in common. These three floras belong to the Ryoseki-type flora.

In this study, I also found many common elements between the floras of the Somanakamura and the Southern Primorye. The comparison between the Soma flora and the flora of the Southern Primorye area is requested.

Keywords: Late Jurassic, Plant fossils, Somanakamura Group, Ryoseki-type flora,
South Kitakami

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Chapter 1
Introduction

This study deals with the plant macrofossils from the Upper Jurassic Tochikubo and Tomizawa formations, Somanakamura Group in the Outer Zone, Northeast Japan. The Middle Jurassic to lowermost Cretaceous Somanakamura Group crops out in a narrow zone along the eastern margin of the Abukuma Mountains. Yanagisawa et al. (1995) subdivided the Somanakamaura Group into six formations. Among which the Tochikubo Formation, the middle of this group, has been well known to occur abundant fossil plants.

Occurrence of fossil plants from the study area in this paper was first reported by Tokunaga and Otsuka (1930). Oishi (1940) had an opportunity of examining and describing the plant fossils from this area in the collection of the Tohoku University. They were collected by Professor T. Nagao and himself. Oishi (1940) described 12 genera and 18 species from the four localities. During from 1980 to 1984, graduate and undergraduate students of the Tokyo Gakugei University including myself collected a number of fossil plants from the Tochikubo Formation. These specimens were systematically described by Kimura and Tsujii (1984) and Kimura and Ohana (1988a, 1988b), who mentioned the characteristic feature of this plant assemblage. On the other hand, Kimura (1987a, b) proposed a palaeophytogeographic subdivision in Japan and Eastern Eurasia during Late Jurassic to Early Cretaceous. Kimura named the southern and northern provinces as the Ryoseki-type and Tetori-type, while their ecotone as the Mixed-type flora. Kimura and Ohana (1988a) correlated the flora of the Tochikubo Formation with the Ryoseki-type flora, as it is characterized by abundance of *Zamites*, *Ptilophyllum*, matoniaceous ferns, and *Nilssonia* with broad-type leaves.

Since 1996, local collectors, such as M. Taira, Y. Yamaki, Y. Ara and members' of Research Association of the Somanakamura Group have provided plant fossils for my study. More recently, thousands of fossil plants were found from the Tochikubo and Tomizawa formations during the construction of the Joban Highway (Figure1,2), most of which were collected by local collectors and staffs of the Ibaraki Nature Museum. They were extraordinary well preserved and some of them were appeared to be new to science. Therefore, I began to study them with help of Dr. Kimura and Dr. Ohana. What I erected first were two new *Nilssoniocladus* species based on leaves attached with a twig in original position (Takimoto,et al., 1997). Further, new species of *Nilssonia, Peloudea*, *Taeniatus*, *Taeniopteris* and *Zamites* were described (Takimoto et al., 2008). *Lycopodites, Neocalamites*, and *Adiantopteris* were reported from the flora for the first time. Furthermore, I described the new species of *Encephalartites* with Dr Ohana (Takimoto and Ohana, 2016).

One of the purposes of this study is to make the floral character much clearer and to provide supplementally information of newly recognized plant species. In addition, I tried to compare floristic characters of the Soma area with those of the South Kitakami area. Because some studies have already suggested an obvious similarity between Soma and South Kitakami areas in geological and paleontological features. However, paleobotanical study has not done. For study of sedimentation, Takizawa (1985) reported a close similarity in Jurassic sedimentation between the South Kitakami Mountains and the Soma area at the eastern margin of the Abukuma Mountains. Taketani (2013) also correlated the Jurassic Koyamada Formation of the Soma area to the Isokusa Formation of the South Kitakami based on radiolarian assemblage. The radiolarian and ammonite assemblages of both formations exclusively comprise elements of the Tethyan and Pacific biogeographic provinces of the lower to middle latitudes (Taketani, 2013). For the plant fossils, some studies have done about the plant fossils from the Somanakamura Group in the Soma area, Oshika and Shishiori groups in the South

Kitakami area. These groups are same in geological age; from Middle Jurassic to Lower Cretaceous. Kimura et al. (1990) mentioned the similarity in the fossil assemblages from the Somanakamura, Oshika and Shishiori groups. However, Kimura et al. (1990) did not discuss in detail on their constituents nor composition, unless they correlated those three floras to the Ryoseki-type flora. This study discusses the characters of fossil plant assemblage and common species among the three floras in great detail. In this study, I re-investigated more than 3000 specimens of fossil plants include the specimens have reported that have been collected during the past 30 years. Because investigate the specimens from the different point of view was necessary to the comparison of these three floras. They were from 28 sites in Minamisoma City and Soma City, Fukushima Prefecture, Japan (Table 1, Figure 3).

Figure 1. Locality No. 26 Shidazawaike 2005.10.30

Figure 2. Locality No. 23 Shidazawakita 2010.3.14

Table 1. Localities of plant fossils from the Tochikubo and Tomizawa Formation, Somanakamura Group.

No.	Localities	Longitude	Latitude	Formation	Ward, City
1	Umenokizawa	37°45'07.7"N	140°53'56.1"E	Tochikubo	Soma City
2	Kitanoirisawa	37°44'29.6"N	140°53'03.8"E	Tochikubo	Kashima, Minamisoma
3	Oyama	37°43'60.0"N	140°54'33.6"E	Tomizawa	Kashima, Minamisoma
4	Tochikubo	37°43'54.2"N	140°53'26.4"E	Tochikubo	Kashima, Minamisoma
5	Minahara	37°43'22.5"N	140°53'45.8"E	Tochikubo	Kashima, Minamisoma
6	Kabesu-rindo kitashisen	37°42'54.6"N	140°54'17.2"E	Tochikubo	Kashima, Minamisoma
7	Kabesu-rindo	37°42'46.6"N	140°54'23.9"E	Tochikubo	Kashima, Minamisoma
8	Karamatsu-rindo kitashisen	37°42'20.0"N	140°54'26.2"E	Tochikubo	Kashima, Minamisoma
9	Koyamada-rindo	37°42'17.3"N	140°54'34.4"E	Tochikubo	Kashima, Minamisoma
10	Bunasaka	37°42'17.0"N	140°54'29.9"E	Tochikubo	Kashima, Minamisoma
11	Bunasakaike	37°42'12.4"N	140°54'22.9"E	Tochikubo	Kashima, Minamisoma
12	Karamatsu-rindo Minamishisen 1	37°41'58.9"N	140°54'21.5"E	Tochikubo	Kashima, Minamisoma
13	Karamatsu-rindo Minamishisen 2	37°41'56.8"N	140°54'02.9"E	Tochikubo	Kashima, Minamisoma
14	Karamatsu-rindo Minamishisen 3	37°41'50.1"N	140°54'20.8"E	Tochikubo	Kashima, Minamisoma
15	Jisabara	37°41'38.7"N	140°54'04.1"E	Tochikubo	Kashima, Minamisoma
16	Jizomae	37°41'24.3"N	140°54'33.9"E	Tochikubo	Kashima, Minamisoma
17	Tatenosawa 1	37°41'07.1"N	140°54'39.5"E	Tochikubo	Kashima, Minamisoma
18	Tatenosawa 2	37°41'04.3"N	140°54'34.7"E	Tochikubo	Kashima, Minamisoma
19	Tatenosawa 3	37°40'56.6"N	140°54'25.9"E	Tochikubo	Kashima, Minamisoma
20	Fukounonakayama-rindo	37°40'35.9"N	140°54'52.2"E	Tochikubo	Haramachi, Minamisoma
21	Aratozawa	37°40'25.1"N	140°54'41.5"E	Tochikubo	Haramachi, Minamisoma
22	Kayanokibashi	37°39'37.3"N	140°54'50.3"E	Tochikubo	Haramachi, Minamisoma
23	Shidazawakita	37°39'00.9"N	140°55'03.4"E	Tochikubo	Haramachi, Minamisoma
24	Shidazawa-rindo	37°38'52.0"N	140°54'48.9"E	Tochikubo	Haramachi, Minamisoma
25	Shidazawa	37°38'46.7"N	140°55'07.8"E	Tochikubo	Haramachi, Minamisoma
26	Shidazawaike	37°38'45.6"N	140°55'06.4"E	Tochikubo	Haramachi, Minamisoma
27	Okusidazawa	37°38'44.4"N	140°54'57.4"E	Tochikubo	Haramachi, Minamisoma
28	Kitayachi	37°37'45.3"N	140°55'09.8"E	Tochikubo	Haramachi, Minamisoma

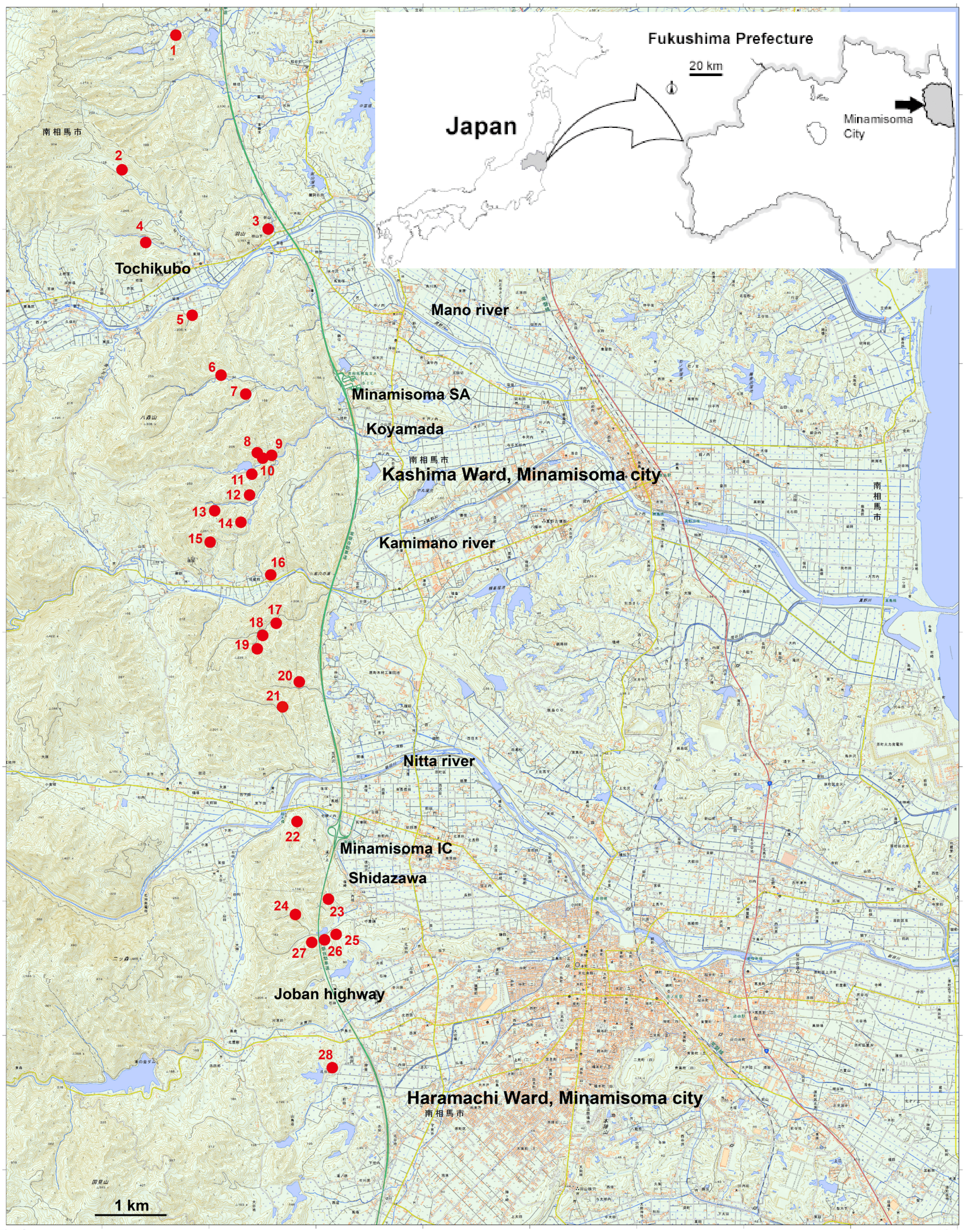


Figure 3. Location of the Minamisoma City and localities of the fossil site mentioned in this paper. Information of Localities shows in Table 1. (part of 1:25000 "Iwakikashima" and "Haramachi" sheet published by the Geographical Survey of Japan)

Chapter 2
Geological Backgrounds

General Remarks

Yanagisawa et al. (1996) described the geology around the Somanakamura district as below.

The Somanakamura district is located in the northeastern margin of the Abukuma Mountains, northeast Japan. In this district, mylonite and cataclastic rocks are associated with the western Hatagawa and eastern Futaba Fracture Zones running from north to south. The two fracture zones, each with a width of 1-3 km, extend over a distance of about 100 km along the eastern margin of the Abukuma Mountains.

Within the Hatagawa Fracture zone, three major faults are recognized: the Western, Central and Eastern Faults. By contrast, the Futaba Fracture Zone is mainly restricted to the Futaba Fault. In addition, northeast-trending Shajigami Shear Zone occurs between the Hatagawa and Futaba Fracture Zones

On the eastern side of the Futaba Fault, Mesozoic formations crop out in contact with the fault. Pliocene sedimentary rocks are widely distributed in the rest of the Somanakamura district. The narrow area between the Futaba and Central Fault is occupied by metamorphic rocks, Paleozoic sedimentary rocks, Lower Cretaceous volcanic and intrusive rocks and Miocene volcanic and sedimentary rocks. On the western side of the Central Fault, "Abukuma- type" granitic rocks occur along with metamorphic rocks and gabbro.

Somanakamura Group

According to Yanagisawa et al. (1996), the Middle Jurassic to Lower Cretaceous Somanakamura Group crops out in a narrow zone along the Futaba Fault, forming a north-south trending anticlinorium. This Group is subdivided into six formations, as shown in Figure 4.

The Awazu Formation lies unconformably over the Karosan Formation. The formation is 280m thick, and consists mainly of black shale. The lowermost part of the formation is composed of coarse to medium grained arkosic sandstone. The basal conglomerate of the formation contains pebbles of graphic and adamellitic granite, and volcanic rocks. It yields bivalves such as *Chlamys awazuensis, Latitrigonia pyramidalis, Vaugonia awazuensis* and *Bigotites* sp. On the basis of these fossils, the formation was assigned to be a late Bajocian or early Bathonian age.

The Yamagami Formation is about 250m thick, and consists mainly of stratified medium-grained sandstone, accompanied by alternating beds of fine to coarse grained sandstone and shale. This formation crops out in the central part of the district and rarely contains marine molluscan fossils.

The Tochikubo Formation consists of arkosic sandstone and shale with intercalated coal seams. This formation yields abundant plant fossils and footprints of dinosaur, but lacks marine fossils, probably because of a non-marine origin.

The Nakanosawa Formation consists mainly of arkosic or calcareous sandstone. In its upper part, it contains impure limestone (Koike limestone Member). The formation is characterized by abundant marine molluscan fossils. In addition, the Koike limestone Member contains abundant fossils of reef-forming organisms, such as stromatoporoids and corals, which are common to the Torinosu-type Fauna (Mori, 1963). This member is probably an Early Tithonian age because of the occurrence of *Aulacophinctoides* cf. *steigeri* (Sato, 1967).

The Tomizawa Formation is composed of arkosic sandstone and shale in thick-bedded alternations, and is lithologically similar to the Tochikubo Formation. This unit lacks marine fossils and is considered to be mostly non-marine in origin.

The Koyamada Formation, the uppermost unit of the Somanakamura Group, is dominated by black shale and interlayered dactic tuff. Most of this formation is Berriasian in age because it yields *Parakilianella umazawaensis* and *Thurmanniceras* sp.

Among these formations, the Tochikubo and Tomizawa formations are non-marine sediments, the other four formations are composed of sedimentary rocks that are shallow-marine to deep sea origin. The total thickness of the group is more than 1900 m. The lithological features, such as sedimentary facies and cycles, and the composition of sand grains are similar to those of the Jurassic strata in the South Kitakami Mountains.

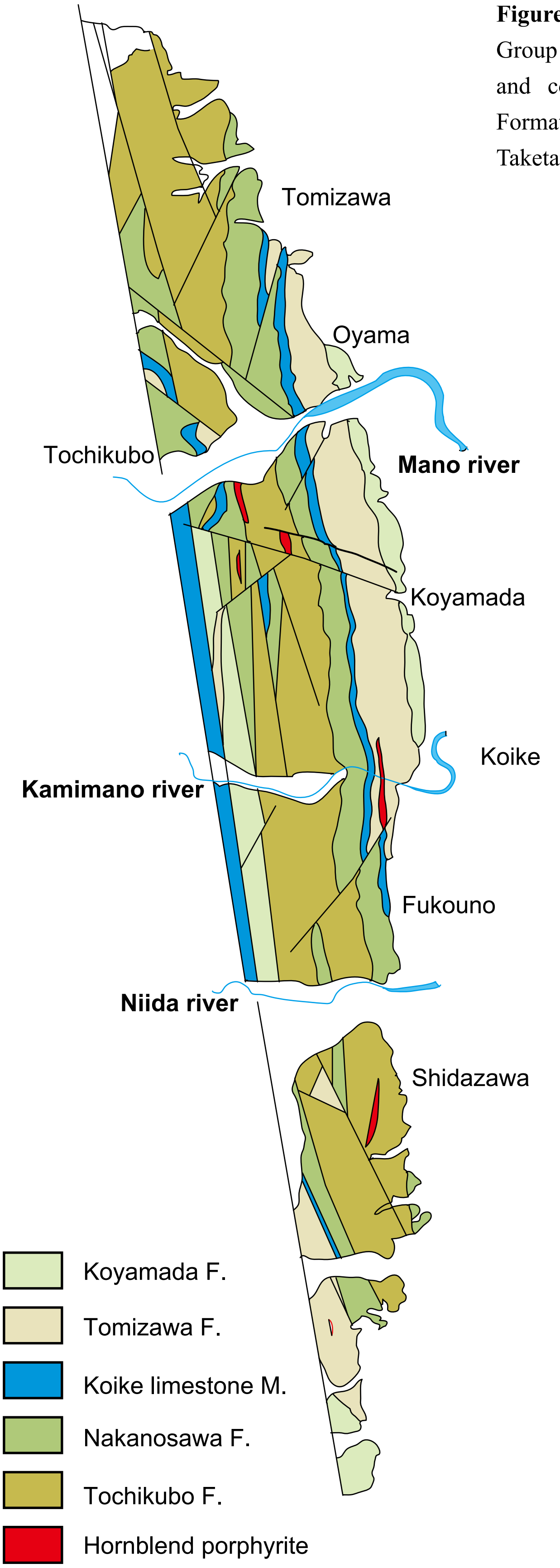
Plant bearing formations

The specimens of this study came from 28 localities in the Somanakamura area of Soma City and Minamisoma City; most of them are exposures of the Tochikubo Formation (Table 1). As shown in Figure 4, this formation occupies the middle part of the Somanakamura Group and consists mainly of coarse-to fine-grained arkosic sandstone and shale. Takizawa (1985) analyzed sedimentary features of the Tochikubo Formation in detail and concluded that it is mostly of non-marine fluvial, near-shore, and lacustrine environments. The middle division of the formation is made up largely of shale-dominated alternation that commonly intercalates thin coal seams and carbonaceous shale. Plant fossils are particularly abundant in this division.

Since the Tochikubo Formation is entirely barren of marine fossils, it is difficult to determine the exact geologic age. However, an Oxfordian age has been presumed on the basis of the stratigraphic relationship with the overlying Nakanosawa and the underlying Yamagami formations (e.g., Masatani and Tamura, 1959; Mori, 1963); both of them yield abundant marine fossils.The other plant-bearing formation is the Tomizawa Formation, which is situated in the upper part of the Somanakamura Group. In this study, only one locality: number 3 "Oyama" is exposure of the Tomizawa Formation. Plant fossils are rather scanty throughout at this locality, but Masatani and Tamura (1959) listed several species of *Podozamites, Onychiopsis*, and others. The author newly confirmed the occurrence of fragmentary reproductive organ assignable to *Williamsonia* sp.

Geologic Age			Formation	Thickness	Lithology	Fossils
Cret.	Berriasian	Somanakamura Group	Koyamada Fm	160m	Shale with sandy intercalations and dacitic tuff	Ammonoidea Radiolaria
Jurassic	Tithonian		Tomizawa Fm	400m	Coarse sandstone and shale	Plants
	Kimmeridgian		Nakanosawa Fm	140m	Coarse sandstone, limestone with sandy shale	Ammonoidea Coral Bivalvia
	Oxfordian		Tochikubo Fm	350m	Coarse to fine sandstone and shale	Plants Dinosaur
	Callovian		Yamagami Fm	200m	Massive medium sandstone with shale	Bivalvia *Latitrigonia unicarinata* *Ibotrigonia masatanii*
	Bathonian Bajocian		Awazu Fm	160m	Shale or sandy shale, fine sandstone and conglomerate	Trigoniidae Bigotites sp. *Latitrigonia pyramidalis*
?			Karosan Fm	?	Coarse to medium sandstone with shale	

Figure 4. Stratigraphic succession of the Jurassic in the Soma area (modeffied from Takizawa, 1985).



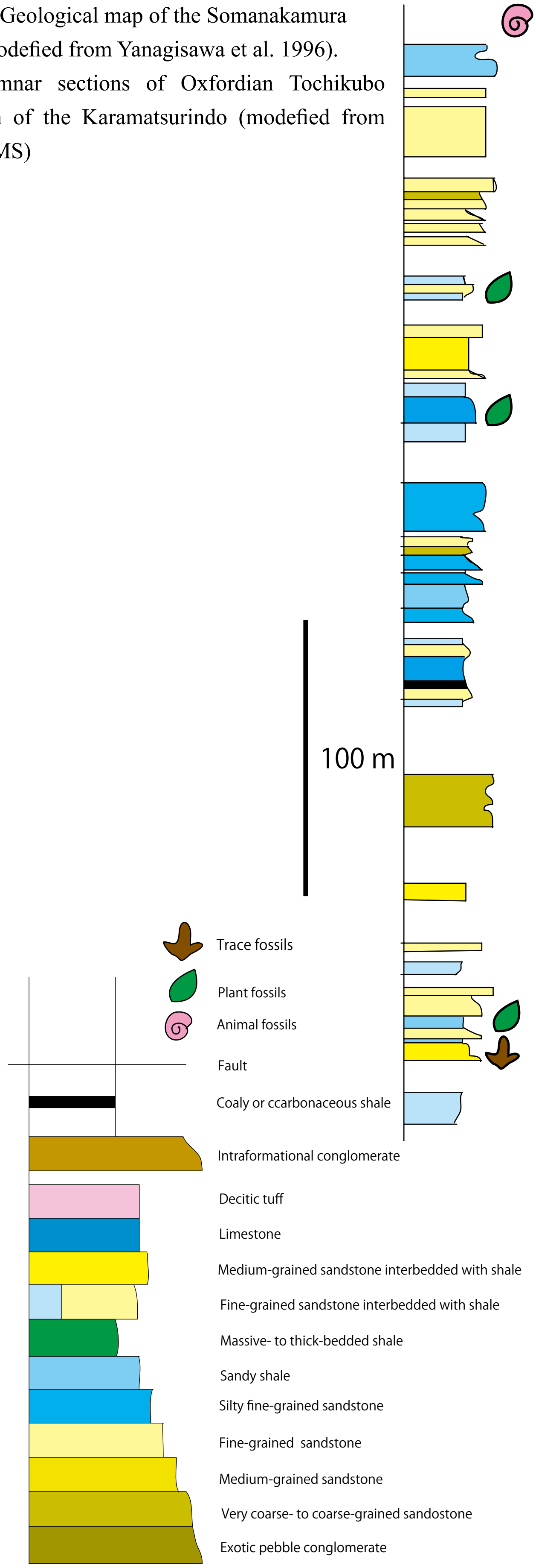
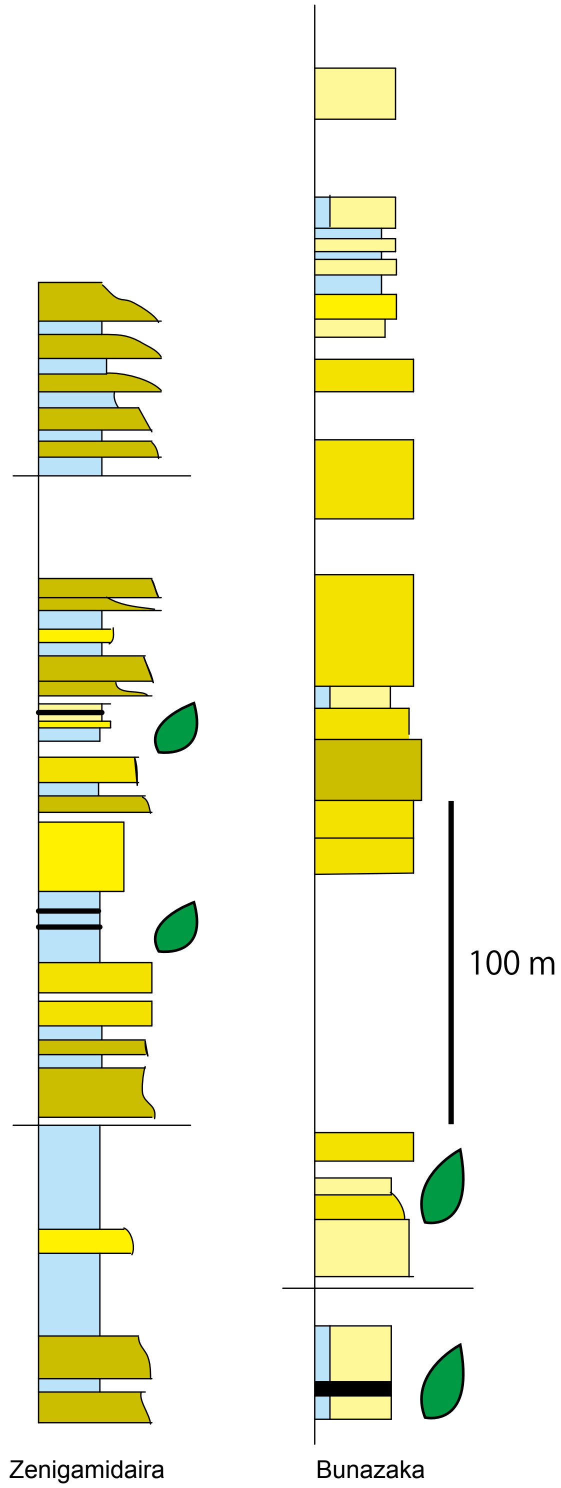


Figure 5. Geological map of the Somanakamura Group (modefied from Yanagisawa et al. 1996). and columnar sections of Oxfordian Tochikubo Formation of the Karamatsurindo (modefied from Taketani MS)

from the locality. The Tomizawa Formation consists mainly of coarse-grained sandstone and shale in thick-bedded alternations that indicate non-marine environments. Although the Tomizawa Formation lacks any age diagnostic marine fossils, its geologic age is considered to be late Tithonian (Yanagisawa et al., 1996). As mentioned above, plant fossils described in this paper are preserved in the Upper Jurassic non-marine terrigeneous sedimentary rocks accompanied with a thick sequence deposited in shallow to offshore marine environments. Takizawa (1985), Okami (1969), and others investigated sedimentary petrology and sedimentology of the Somanakamura Group: they showed that the unit primarily covered unconformably upon the basement complex of the Abukuma Mountains.

Ito and Taketani investigated the sedimentary environment of the Somanakamura Group from 2014 to 2015 (Ito and Taketani, MS). They concluded that deposition of the Tochikubo Formation was started from a braided stream, meandering river, and delta to the upper part. They further recognized a ravinement surface at the uppermost part of the Tochikubo Formation. The Tomizawa Formation also shows a same pattern of deposition with the Tochikubo Formation.



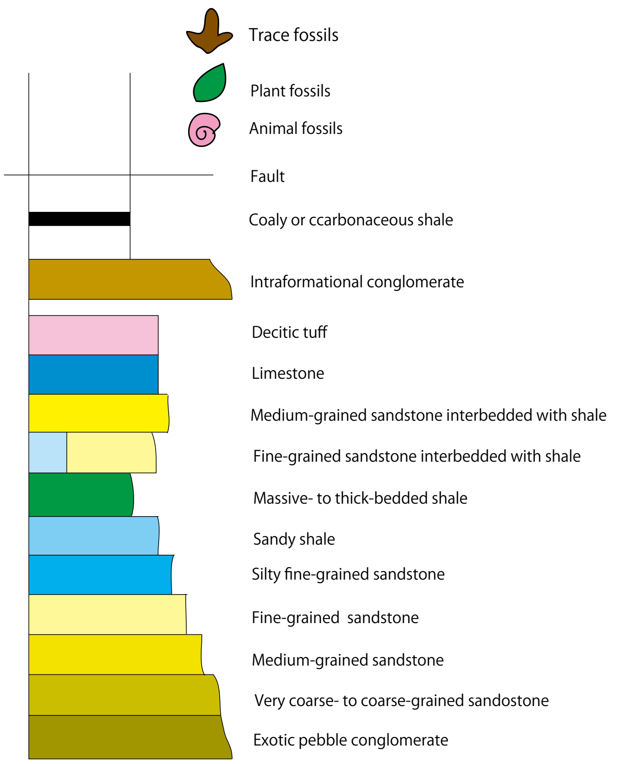


Figure 6. Stratigraphical succession of the Jurassic in the Soma area (modefied from Takizawa 1985).

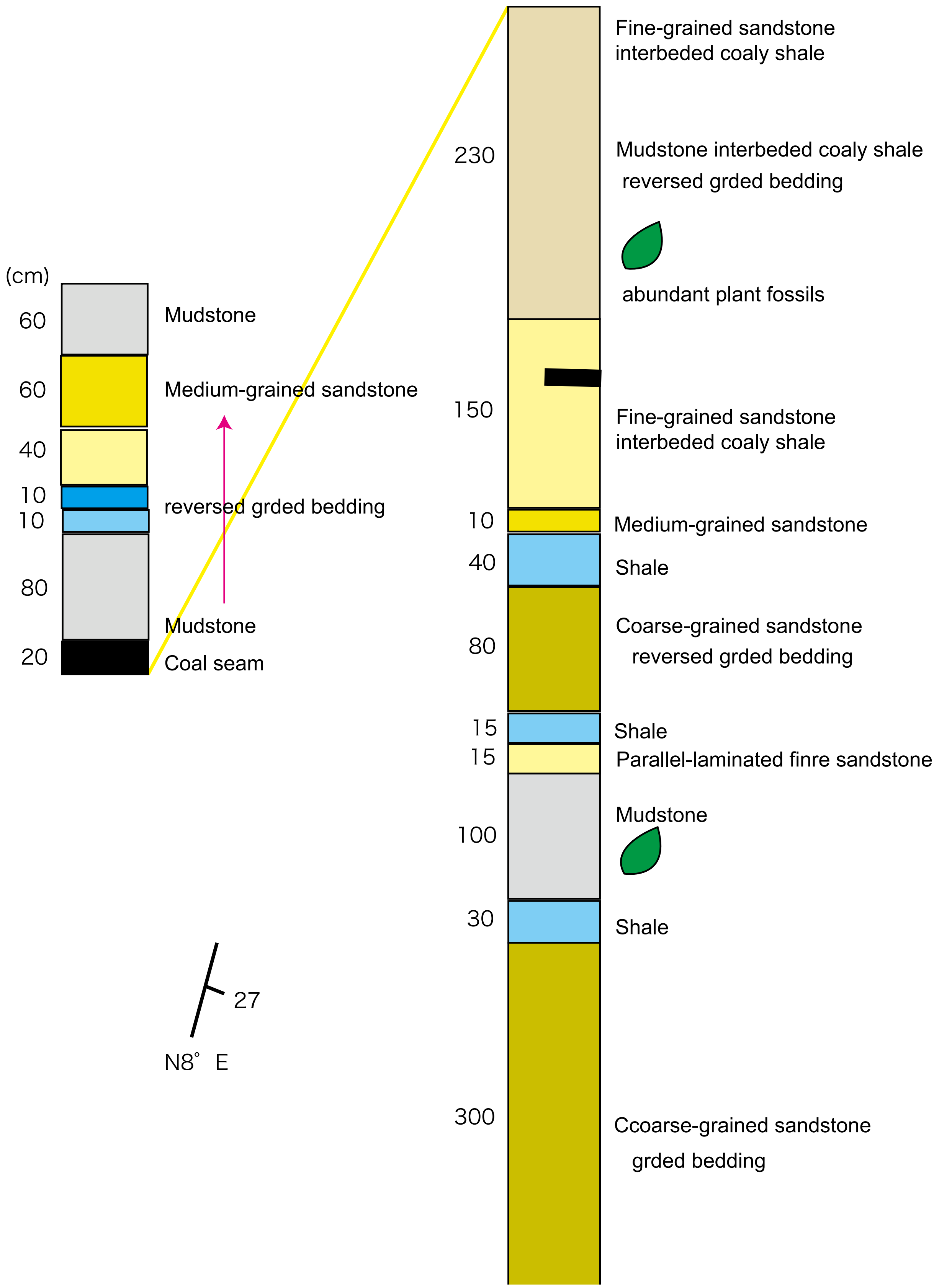


Figure 7. Detailed measured succession of the upper part of the Tochikubo Formation at Shidazawa.

Chapter 3
Material and Methods

More than 3000 specimens have been collected from the 28 fossil sites in Minamisoma City and Soma City, Fukushima Prefecture, Japan (Table 1, Figure 3). They have been collected by local collectors, students of Tokyo Gakugei University, staff of Geological laboratory of the Ibaraki Nature Museum and myself. They are stored in the National Museum of Nature and Science Tokyo, Minamisoma City Museum, Fukushima Museum, Ibaraki Nature Museum and local collectors houses (Table 2). The specimens stored in the Kashima History and Folklore Museum have already moved to the Minamisoma Museum. All specimens are preserved as impressions, thus lacking cuticles. The fossils were found in fine-grained sandstone, silty fine-grained sandstone and shale. Photographs of the materials were performed with a Nikon D7000 digital camera with oblique lighting.

Repository

NSM PP: National Museum of Nature and Science, Tokyo

KHFM: Kashima History and Folklore Museum (move to Minamisoma Museum)

MM: Minamisoma City Museum

N: Fukushima Prefectural Museum

INM: Ibaraki Nature Museum

SDS'05: Ibaraki Nature Museum (local collection number)

NSDS: Ibaraki Nature Museum (local collection number)

Tc Cayton: Ibaraki Nature Museum (local collection number)

ARA: Personal collection of Yoshimi Ara

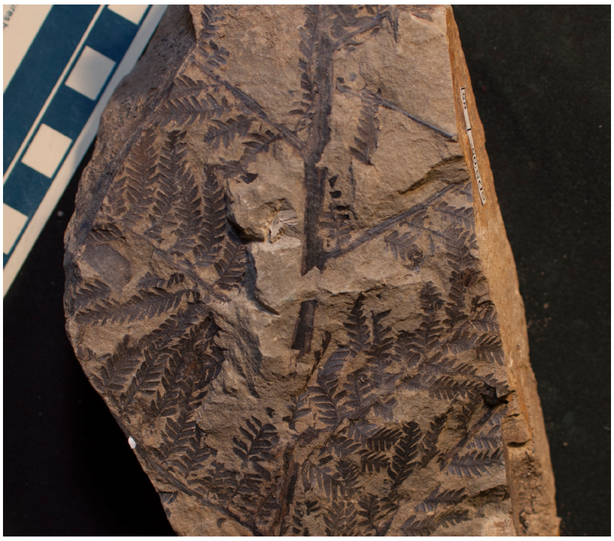


Figure 8. fossil plant in the silty fine-grained sandstone.

Figure 9. fossil plant in the fine-grained sandstone.

Figure 10. fossil plant in the sandy shale.

Table 2. The museums stored the fossil plants specimens from the Somanakamura Group.

	Plants	National S. M.	Ibaraki N. M.	Minamisoma M.	Fukushima M.
1	Lycoposites sp.			KHFM-210020, 210040	
2	*Equisetites* sp.		SDS'05-268,619,620		
3	*Neocalamites* sp.			KHFM-210037, 210038	
4	*Gleichenites* sp. A	8142-8157,			
5	*Matonidium* ex gr. *goepperti*	8158-8169,			
6	*Eboracia microlobifolia*	8170-8190			
7	*Onychiopsis elongata*				N201200016
8	*Onychiopsis yokoyamai*		SDS'05-774,779,780,811		N201200054
9	*Adiantopteris* sp.			KHFM-210022	
10	*Acrostichopteris* sp. A	8240, 8241			
11	*Acrostichopteris* sp. B		SDS'05-49,50,54,57		
12	*Cladophlebis acutipennis*	8201-8206			
13	*Cladophlebis* sp. cf. *C. matonioides*	8207-8211			
14	*Cladophlebis* sp. cf. *C. vieginiensis*	8212-8229			
15	*Cladophlebis* sp. A	8230-8234			
16	*Cladophlebis* sp. B	8235-8239			
17	*Cladophlebis* sp. C		SDS'05-89,226		
18	*Cladophlebis* sp. D		SDS'05-461		
19	*Cladophlebis* sp. E		SDS'05-709		
20	*Cladophlebis* sp. F		SDS'05-85,147		
21	*Sphenopteris elegans*	8191-8200			
22	*Sphenopteris* sp.A		SDS'05-86		
23	*Sphenopteris* sp.B		SDS'05-234		
24	*Sagenopteris* sp.		Tc Cayton 1-7		
25	*Caytonia* sp.		Tc Cayton 1,8		
26	*Otozamites* sp. cf. *kondoi*	8242, 8243, 8244			N201200020
27	*Zamites brevipennis*	8294, 8295		KHFM-210023, 210024	
28	*Zamites nipponicus*	8245-8254			
29	*Zamites* sp. A	8255			
30	*Zamites* sp. B	8256			
31	*Ptilophyllum jurassicum*	8258-8285	SDS'05-41,44,342		
32	*Ptilophyllum linearifolium*				N201200014, N2012(
33	*Ptilophyllum* sp. cf. *oshikaense*				N201200056
34	*Ptilophyllum* sp. F	8286, 8287, 8288			
35	*Ptilophyllum* sp. G	8289			
36	*Ptilophyllum* sp. H	8290-8293			
37	*Nipponoptilophyllum bipinnatum*	8399-8418			
38	*Weltrichia* sp. A		SDS'05-449		
39	*Weltrichia* sp. B		SDS'05-802		
40	*Weltrichia* sp. C		SDS'05-589		
41	*Williamsonia* sp.			KHFM-210025, 210026	
42	*Pseudoctenis* sp. A	8296, 8297			N201200090
43	*Nilssonia* sp. cf. *N. Canadensis*	8298-8303	SDS'05-64,105,543		
44	*Nilssonia* sp. cf. *N. densinervis*	8304-8310			
45	*Nilssonia longipinnata*	8311-8318			
46	*Nilssonia oblique-truncata*	8319-8331			
47	*Nilssonia* ex gr. *Schaumbuegensis*	8332-8345			
48	*Nilssoniocladus tairae*			KHFM-210005-210011, 210016	
49	*Nilssoniocladus japonicus*			KHFM-210001-210004, 210018, 210019	
50	*Cycadites* sp.	8346-8349			
51	*Encephalartites nipponensis*		4-013792-013795	008487, 008488-008496	
52	*Elatocladus* sp. A	8350, 8351			
53	*Pagiophyllum* sp.	8373-8386			
54	*Parasequoia* sp. cf. *P. cretacea*	8352-8372			
55	Carpolithes sp. A	8387-8398			
56	Taenoatus elongatus			00108-376-024G	
57	Taeniopteris somaensis			KHFM210034	
58	Peloudea nipponica	8419-8423		MM210032, 210033	

National Museum of Nature and Science, Tokyo: 4-1-1 Amakubo, Tsukuba, Ibaraki, 305-0005, Japan.
Minamisoma City Museum: 194 Deguchi, Gorai, Haramati, Minamisoma, Fukushima, 975-0051, Japan.
Fukushima Museum: 1-25, Joutou, Aizuwakamatsu, Fukushima, 965-0807, Japan.
Ibaraki Nature Museum: 700, Osaki, Bando, Ibaraki, 306-0622, Japan.

Chapter 4
Systematic Descriptions

Pteropsida

Lycopodiales

Genus ***Lycopodites*** Lindley and Hutton, 1833.

Lycopodites sp.

Plate I, 1, 2; Figure 11, 3,4

Material: KHFM-210020 (Karamatsu-rindo minamishisen 3), 210040 (Kayanokibashi).

Locality: Kayanokibashi and Karamatsu-rindo minamishisen 3, Kashima Ward, Minamisoma City, Fukushima Prefecture.

Strata: Tochikubo Formation (Oxfordian), Somanakamura Group.

Description

Two forms of shoots are obtained; one is thick and the other is thin. The thin shoot (Plate I, 1, Figure 11, 3) is herbaceous and consists of slender branched axes covered with small, isophyllous, scale-like leaflets. The leaflets are spirally arranged or in whorls, 4 mm long and up to 2.5 mm wide; the abaxial surface is convex each with a distinct keel and an adaxial surface is concave, and their distal half is falcate with acutely pointed apex. No reproductive organs are found. The thick shoot is about 3.5 cm long and 1.5 cm wide (Plate I, 2, Figures 11, 4). (Original description in Takimoto et al., 2008)

Remarks

There is no morphological divergence between the thin and thick shoot. Externally, the both shoots are herbaceous, because of their thin leaves. Coniferous leaves of this type have a lozenge-shaped cross section. The leaves of present specimens are too thin to decide the plants are conifer. Differences of size between the shoot and its daughter shoots occurred that the shoots are buried under the rock or not. Hence, these are not small woody coniferous twigs. The thick shoot appears to be herbaceous. Another herbaceous genus that coexisted with the Jurassic arborescent lycopod is *Selaginellites*. Since the specimens are sterile impressions and no ligule at leaf bases, we do not have any sufficient data to place them in *Selaginellites*. Therefore, we adopt the generic name *Lycopodites* for these specimens at present. Kimura (1976) described *Lecopodites* from the Yatsushiro Formation, Southwest Japan; however, all of the specimens are ill-preserved small fragments of sterile foliage. Therefore, it is difficult to compare with the present specimens.

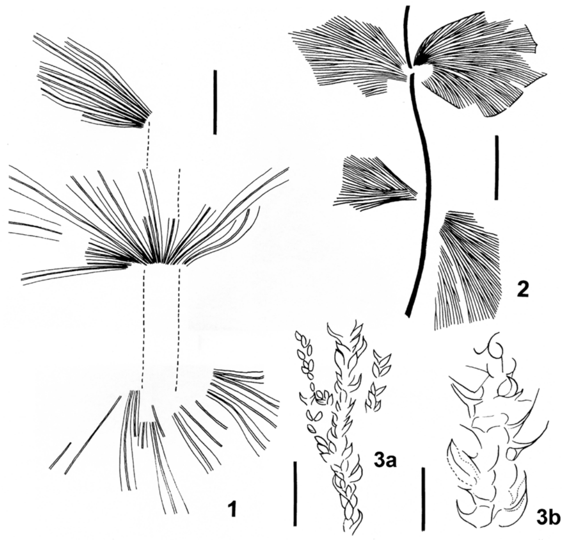


Figure 11. 1. *Neocalamites* sp. (KHFM 210037). **2.** *Adiantopteris* sp. (KHFM 210022). **3.** Lycopodites sp. **3a.** (KHFM 210020) **3b.** (KHFM210040). after Takimoto et al. (2008)

Equisetales

Family Equisetaceae

Genus ***Equisetites*** Sternberg,1833

Equisetites sp.

Plates I, 3

Material: SDS’05-268, 619, 620 (Shidazawaike) and 20 other specimens (Shidazawa).

Locality: Shidazawaike and shidazawa, Haramachi Ward, Minamisoma City, Fukushima Prefecture.

Strata: Tochikubo Formation (Oxfordian), Somanakamura Group.

Remarks

Several imprints of broken aerial stems and detached diaphragms were obtained. The aerial stems are 0.5 cm wide; its internode is 1 cm long.

Genus ***Neocalamites*** Halle, 1908

Neocalamites sp.

Plate II, 1; Figure 11, 1

Material: KHFM 210037, 210038(counter part).

Locality: Karamatsu rindo minamishisen 1, Kashima Ward, Minamisoma City, Fukushima Prefecture.

Strata: Tochikubo Formation (Oxfordian), Somanakamura Group.

Description

Small and incomplete specimen with internodes and three broken leaf-whorls. Nodal regions are missing. Estimated length of internode attains more than 5 cm long; each whorl is 3.5 mm wide and has five to 13 leaves with a distinct mid-vein.

Remarks

This leafy shoot resembles those of *Neocalamites, Calamites*, *Schizoneura*, *Phyllotheca*, *Annularia*, and *Asterophyllites* . These genera except *Phyllotheca* and *Neocalamites* disappeared before Early Jurassic. *Neocalamites* is a Mesozoic genus of large *Calamites*-like stems and leafy shoots. It is still imperfectly separated by morphological characters from *Calamites*, but is a useful group even if not perfectly defined. The genus *Phyllotheca* is a well-known Sphenophyta in the Upper Carboniferous to Lower Cretaceous rocks world-wide. Leaves of *Phyllotheca* joined basally in a sheath. This leafy shoot, however, lacks a sheath. In the Equisetaceae, the genera except *Neocalamites* have whorls of microphyll-like leaves that are more or less fused to form a collar or sheath around the node. Therefore, there is no possibility that the present specimen belongs to other lineages of Equisetaceae. It is also difficult to provide a new species name to the present specimen because of its incomplete preservation. We prefer to conclude that the present specimen belongs to *Neocalamites*.

Neocalamites is locally abundant at about the end of the Triassic Period, but the genus became rarer in Early Jurassic(Harris 1961). *Neocalamites* is common in the Carnian to Norian Nariwa Group and Mine groups in Japan. *Neocalamites* is seemed to be extinct in the early Middle Jurassic (Schweitzer et al. 1977). Thus, this is the youngest occurrence of the genus *Neocalamites* in Upper Jurassic rocks.(Original description and remarks in Takimoto et al., 2008)

Order: Filicales

Family: Gleicheniaceae

Genus: ***Gleichenites*** Geoppert, 1936

Gleichenites sp. A

Plate II, 2-5; Figure 12, 1

Material: NSM PP-8142 - 8150 (Shidazawa), 8151 - 8157 (Bunasaka).

Locality: Shidazawaike and Bunasaka, Haramachi Ward, Minamisoma City, Fukushima Prefecture.

Strata: Tochikubo Formation (Oxfordian), Somanakamura Group.

Description

Leaf is at least tripinnate, but its whole shape is uncertain. Ultimate pinnae are set closely, and attached alternately to the rather thick pinna axis, 2 mm wide at an angle of 45-50 degrees. Pinnules are also set closely, elongate-triangular in form, typically 8 mm long and 2 mm wide at middle, attached katadromically to the pinna axis at an angle of 80-90 degrees, and sometimes falcate. Margins are divided into up to 7 pairs of shallow lobes; each lobe is rather directed forwards, and with rounded or obtusely pointed apex. The lobes of the first pair are larger in size, twice as large as others. Venation is obscure ; midnerve persists to the tip but lateral veins are invisible. Sori (?) are faintly preserved, 0.5-1 mm in diameter, each occurring on the centre of a lobe of basal 1-3 pairs, but details of soral characters are uncertain. (Original description in Kimura and Ohana, 1988a)

Remarks

Gleichenites? sp. A is characterized by its tripinnate leaf bearing markedly lobed pinnules. In external form of pinnules, *Gleichenites*? sp. A is most close to *Sphenopteris* (*Gleichenites*?) *erecta* originally described by Bell (1956) from the Aptian Luscar and Albian Blairmore Formations, Western Canada. But it is impossible to make detailed comparison of our leaves with the Canadian ones because of ill preservation of both materials. Supplementary specimen has not found after Kimura and Ohana (1988a).

Family Matoniaceae

Genus ***Matonidium*** Schenk, 1871

Matonidium ex gr. ***goepperti*** (Ettingshausen) Schenk

Plate III, 1-4; Figure 12, 2

Comparable specimens: *Alethopteris goepperti* Ettingshausen: Ettingshausen, 1852, p. 1 6, pl. 5, figs. 1-7 (Lower Cretaceous of North Germany). *Matonidium goepperti* (Ettingshausen) Schenk: Schenk, 1871, p. 219, pl. 27, fig. 5; pl. 28, figs. 1-2; pl. 30, fig. 3 ; pl. 42, fig. I (ditto); Harris, 1961, p. 1 12, text-figs. 37-38 (Middle Jurassic of Yorkshire) ; Krassilov, 1967, p. 112, pl. 1 2, fig. 4 (Lower Cretaceous of Southern Primorye).

Material: NSM PP-8158 (Aratozawa), 8159-8169 (Shidazawaike) and 31 other specimens.

Locality: Aratozawa and Shidazawaike, Haramachi Ward, Minamisoma City, Fukushima Prefecture.

Strata: Tochikubo Formation (Oxfordian), Somanakamura Group.

Description

Obtained are all broken pinna fragments including only two basal arms. The pinnae are long and slender, up to 2.2 cm wide, but their whole length is unknown. The pinna axis is smooth, projecting more below than above, slender, 1 mm wide at base and 0.5 mm wide above, and sends off closely set pinnules at an angle of 60-90 degrees to the pinna axis. The pinnules on the middle portion of pinna are typically 2-3 mm wide near base and 2 cm long, narrowing gradually towards the obtusely pointed apex and often falcate; those on the basal apical regions of pinna are smaller in size, and their bases are expanded and connected with each other by a web of lamina about 0.5 mm wide. Margins are mostly entire, often strongly reflexed especially when fertile. The midnerve is marked on the under-side of pinnule; in. large-sized sterile pinnules, the midnerve sends off about 20 pairs of mostly twice forked lateral veins (Figure 12, 2b), but in small-sized sterile pinnules, the lateral veins are mostly once forked. In fertile pinnules, the midnerve sends off about 10 paris of mostly once forked lateral veins. In the fertile pinnules, the midnerve sends off about 10 pairs of mostly once forked lateral veins. The sori are superficial, about 0.5 mm in diameter, each just on the branching-point of lateral vein; in some cases sori become square in surface view because of pushing laterally one another and the surface of lamina is usually bulging above each sorus (Figure 12, 2c). The placenta is prominent; ending in a persistent indusium, about 0.25 mm in diameter. The details of sporangia are uncertain. (original description in Kimura and Ohana, 1988a)

Remarks

It is evident that the leaves are with matoniaceous affinity because of the presence of the basal pedate arms and the soral features. It is highly probable that the leaves belong to *Matonidium* and is closely comparable to *M. goepperti* known widely from the Middle Jurassic of Yorkshire and Lower Cretaceous floras of the Wealden-type. But Kimura and Ohana (1988a) reserve to make full identity of our leaves with *Matonidium goepperti* redescribed in detail by Harris (1961), because of the uncertainty of the sporangial features. Sterile pinnules of *Cladophlebis matonioides* originally described by Oishi (1940) and of *C.* sp. cf. *C. matonioides* described in Kimura and Ohana (1988a) are close in form to the present pinnules, but both are distinguished fundamentally from *Matonidium* ex gr. *goepperti* by their tripinnate leaves instead of pedate ones in *M.* ex gr. *goepperti. Matonidium goepperti* recorded by Yabe (1927, p. 51) from the Mone or Kogoshio Formation was, according to Oishi (1940), said to be his *Cladophlebis* *matonioides*. Krassilov (1967) described *Matonidium goepperti* from the Lower Cretaceous of Southern Primorye on the basis of pinna fragments. Its pinnules are shorter in length and correspond in form to basal ones of the pinnae. The first record of occurrence of *Matonidium* from the Japanese Mesozoic was described in Kimura and Ohana (1988a). Supplementary specimen has not found after the paper.

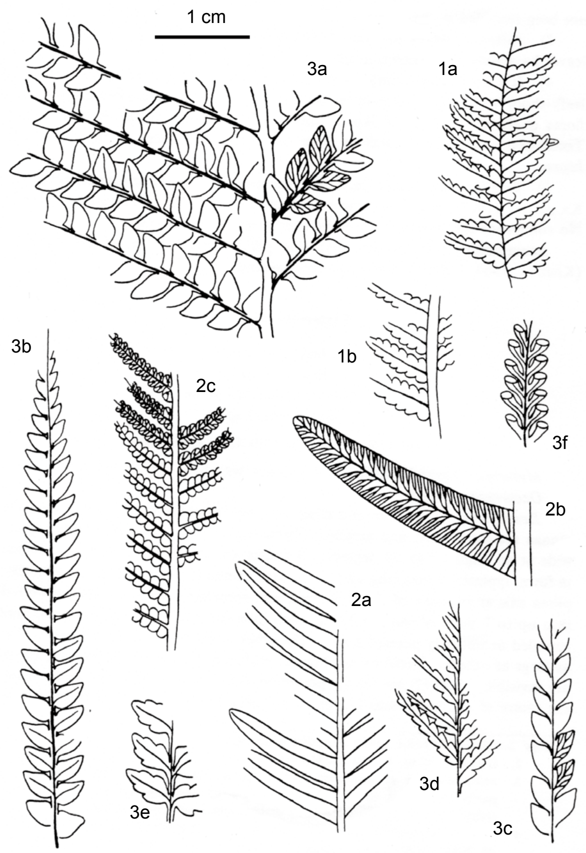


Figure 12. **1.** *Gleichenites* ? sp. A. 1a (NSM PP-8149), 1b (NSM PP-8148) **2.** *Matonidium* ex gr. *goepperti* 2a, 2b (NSM PP-8165), 2c (NSM PP-8164) **3.** E*boracia microlobifolia* 3a (NSM PP-8188), 3b (NSM PP-8170), 3c (NSM PP-8190), 3d (NSM PP-8180), 3e (NSM PP-8184), 3f (NSM PP-8173). after Kimura and Ohana (1988a)

Family Dicksoniaceae

Genus ***Eboracia*** Thomas, 1911

Eboracia microlobifolia Kimura et Ohana

Plates III, 5 and IV, 1-5; Figure 12, 3

Cladophlebis (*Eboracia*?) *lobifolia* (Phillips) Brongniart: Oishi, 1940, p. 273 (pars), pl. 18, fig. 4 (Zusahara).

Eboracia microlobifolia Kimura et Ohana: Kimura and Ohana, 1987a, pl. 1 6, pl. 1, figs. 1-4; text-figs. 2a-h (Ayukawa Formation).

Material: NSM PP-8170-8174, 8183-8190 (Aratozawa), 8175-8182 (Bunasaka) and 505 other specimens.

Locality: Bunasaka, Kashima Ward, Minamisoma City, Fukushima Prefecture. Aratozawa and Shidazawa, Haramachi Ward, Minamisoma City, Fukushima Prefecture.

Strata: Tochikubo Formation (Oxfordian), Somanakamura Group.

Description

Leaf is small- or medium-sized, at least bipinnate, elongate elliptic in form, more than 13.5 cm long and 6 cm wide, and with slender rachis (1 mm wide) with a median groove above, but its whole length is still unknown. Sterile pinnae are closely set, long and narrow, typically 5 cm long or more and up to 7 mm wide at base, gradually narrowing to the acutely pointed or acuminated apex, attached to the rachis at an angle of 65 degrees, and bearing 24-30 pairs of pinnules typically. Pinnules are closely set, katadromic in order, rhomboidal or deltoid in outline, with contracted base, typically 3 mm long and 1.2 mm wide and with entire margins; larger pinnules are sometimes divided shallowly into two pairs of lobes; each obtusely pointed apex. Basal pinnules are not specialized. Veins are of *Sphenopteris* (or Eboracia)-type, symposially disposed; the midnerve sends off 3-4 alternate pairs of lateral veins; sometimes lateral veins of the basal pair are twice forked, but the others are once forked or simple. Fertile pinnae are also long and narrow, as long as sterile ones, bearing closely set fertile pinnules, but basal several pairs are sterile. Lamina of the fertile pinnule is reduced and each bears a single sorus at the tip or acroscopic side. Indusium is cylindrical, but sporangia are indistinct. (Original description in Kimura and Ohana, 1988a)

Remarks

This species is first described by Kimura and Ohana

(1987a) on the basis of a number of sterile and fertile leaf-fragments obtained from the Kiyosaki Sandstone Member (late Tithonian-Berriasian?), Ayukawa Formation, Oshika Group. The present leaves are fully referable to those of *Eboracia microloblfolia*. Some description added to the original one such as of lobed sterile pinnules in Kimura and Ohana (1988a). Comparison of *Eboracia microloblfolia* with *E. loblfolia* (Philips) Thomas and *Cladophlebis novopokrovskii* Prynada was already made in previous paper (Kimura and Ohana, 1987a). From the Lower Cretaceous Oguchi Formation of the Tetori Supergroup in the Inner Zone of Japan, three *Eboracia* species, *E. ishikawaensis*, *E. nipponica* and *E. tetoriensis* have been recognized. However they are all distinguished from *Eboracia microloblfolia* by the position of sori and the size and venation of pinnules. In the Ryoseki-type floras, the dicksoniaceous ferns have not been recognized in the Lower Cretaceous plant-beds in the Outer Zone of Southwest Japan. On the other hand, only two dicksoniaceous genera each with a single species including the present *Eboracia microloblfolia* have been found in the Upper Jurassic plant-beds in the Outer Zone of Northeast Japan. *Eboracia microloblfolia* have been occurred abundantly from many localities in the Soma area.

Unclassified ferns

Genus ***Onychiopsis*** Yokoyama, 1889

Onychiopsis yokoyamai (Yabe) Kimura et Aiba

Plate V, 1-3,5

Sphenopteris yokoyamai Yabe: Yabe, 1927, p. 223, pl.23, figs. 1-2. For further synonyms, see Kimura and Aiba, 1986, p.44.

Material: Ara-1-3 (Oyama), N201200054 (Shidazawa), SDS’05-774, 779, 780, 811 and other five specimens (Shidazawaike).

Locality: Oyama (Tomizawa F.) Kashima Ward, Minamisoma City, Fukushima Prefecture; Shidazawa (Tochikubo F.) and Shidazawaike (Tochikubo F.) Haramachi Ward, Minamisoma City, Fukushima Prefecture.

Strata: Tomizawa Formation (Tithonian) and Tochikubo Formation (Oxfordian), Somanakamura Group.

Description

Frond bipinnate. Rachis thin, 2 mm wide at middle. Pinnae closely set, overlapping each other laterally, alternate or subopposite, linear or elongate-lanceolate, gradually narrowing towards the apex. Pinnules rhombic or rhomboidal in form and attached to thee pinna axis at angle of 30-40 degrees. Venation typical Sphenopteris-type and delicate. Fertile pinnules similar in form to sterile pinnules with entire margins however, different in size, typically 0.4 cm long and 0.1 cm wide.

Remarks

The leaf fragments of sterile and fertile pinna are obtained. They are familiar with the leaves of *Onychiopsis yokoyamai* established by Kimura and Aiba (1986) on the basis of a number of leaves with the fertile part, it is certifiable that the present pinna fragments belong to those of *Onychiopsis yokoyamai*. *Onychiopsis yokoyamai* is one of the common elements of the Late Jurassic-Early Cretaceous Ryoseki-type floras restricted in distribution in the Outer Zone of Japan. Typical types of the leaves of *Onychiopsis yokoyamai* were shown in detail by Kimura and Aiba (1986) together with the detailed comparison of this species with other *Onychiopsis* species. The present specimen agrees well in form with those of *Onychiopsis yokovamai* as shown in their text-figs. 4L7.

Onychiopsis sp. cf. ***O. elongata*** (Geyler) Yokoyama

Plate V, 4

Material: N201200016,

Locality: Shidazawa, Haramachi Ward, Minamisoma City, Fukushima Prefecture.

Strata: Tochikubo Formation (Oxfordian), Somanakamura Group.

Description

The leaf is tripinnate, Rachis thick, 5-6 mm wide at middle. Pinnae closely set, overlapping each other laterally, alternate, linear or elongate-lanceolate, gradually narrowing towards the apex. Pinnules rhombic or rhomboidal in form and attached to thee pinna axis at angle of 30 degrees. Margins of Pinnules are sometimes lobed and pinnatified. Venation typical Sphenopteris-type and delicate.

Remarks

Onychiopsis elongata known abundantly from the Middle Jurassic Utano Formation, Upper Jurassic Kiyosue Formation and Kuzuryu Group and the Lower Cretaceous Itoshiro Group in the Inner Zone in Japan. This is the first record of *Onychiopsis elongata* from the Outer Zone in Japan

Form-genus ***Adiantopteris*** Vassilevskaja, 1968

Diagnosis: Vassilevskaja (1968) proposed a new generic name *Adiantopteris* in place of *Adiantites* Schimper. *Adiantopteris* is similar to the extant genus *Adiantum* whose range from Late Jurassic. Pinnae are flabelliform in shape and opposite. Pinna attached to the axis with a short petiole or directly. Veins are numerous, repeatedly forking dichotomously, and radiating distally.

Adiantopteris sp.

Plate VI, 1; Figure 11, 2

Material: KHFM-210022

Locality: Jizomae, Kashima Ward, Minamisoma City, Fukushima Prefecture.

Strata: Tochikubo Formation (Oxfordian), Somanakamura Group.

Description

The specimen is a part of broken branch. The axis is very slender, 1-1.5 mm wide, from which originates widely separated and oppositely arranged pinnae that are sessile and at nearly right angles to the rachis. The inter-nodes are 2 cm long. Pinnae (or pinnules) are oval in form, about 2 cm long and up to 1.8 cm wide; lateral margins are entire and distal margins are shallowly crenulated. Veins are numerous, originated from contracted base of the pinna, radiating distally, and repeatedly forking dichotomously, 24 per cm in density at middle.(Original description in Takimoto et al., 2008)

Remarks

Although the present specimen is poorly preserved, it is referable to the form-genus *Adiantopteris*.

Three species of *Adiantopteris* were recorded in Japan and adjacent regions such as: *A. sewardi* (Yabe) Vassilevskaja; the Lower Cretaceous Nakdong (Naktong) Formation (Korea) and the Tetori Group (Inner Zone of Japan). *A. toyoraensis* (Oishi) Vassilevskaja; the Lower Cretaceous (or Upper Jurassic) Kiyosue Formation, West Japan and the Lower Cretaceous Monobe Formation (Outer Zone of Japan). *A. yuasensis* (Yokoyama) Vassilevskaja; the Lower Cretaceous Yuasa Formation (Outer Zone of Japan).

Adiantopteris sewardi has a short decurrent petiole. Crenulated margin of the specimen is different from the emarginated lamina found in *A. sewardi*. Furthermore, the specimen has opposite pinnules with many similar veins unlike *A. yuasensis* that has alternately disposed pinnules with a midvein.

The authors refrain from the species assignment because of poor preservation.

Form-genus ***Acrostichopteris*** Fontaine, 1889, em. Berry, 1911

Acrostichopteris sp. A

Plate VI, 3; Figure 13.1

Material: NSM PP-8240, 8241 (Bunasaka)

Locality: Jizomae, Haramachi Ward, Minamisoma City, Fukushima Prefecture.

Strata: Tochikubo Formation (Oxfordian), Somanakamura Group.

Description

Plate VI, 3 shows a single broken pinna with a long stalk, 2 cm long. Lamina is divided possibly into two parts by a deep sinus reaching at the top of stalk. A part of the lamina is further divided into six ribbon-like lobes up to 3.5 mm wide; apices of lobes are all missing. Veins are 1 or 2 at the base of a part, forking dichotomously 3 or 4 times; each lobe receives 4 parallel veins. (Original description in Kimura and Ohana, 1988a)

Remarks

The specimen is quite incomplete, but it was originally a stalked pinna with semicircular lamina divided into two nearly equal parts by a deep sinus. If above-mentioned supposition is true, a point indicated by an arrow in Figure 13,1 shows the bottom of the median sinus of lamina and the right half of lamina is mostly missing. The specimen reminds me of a stalked pinna of such plant as a non-committal genus *Acrostichopteris*. But its incompleteness led me to regard it as *Acrostichopteris*? sp . It is worth mentioning that such pinnae as the present specimen are often en-countered in the Ryoseki-type floras. They have often been confused with ginkgoalean leaves.

Acrostichopteris sp. B

Plate VI, 2, 4, 5

Material: SDS'05-49, 50, 54, 56, 57, six other specimens (Shidazawaike).

Locality: Shidazawaike, Haramachi Ward, Minamisoma City, Fukushima Prefecture.

Strata: Tochikubo Formation (Oxfordian), Somanakamura Group.

Description

Lamina is divided into several parts by a deep sinus parallel with the veins. A part of the lamina is further divided into ribbon-like lobes; apices of lobes. Veins are one at the base of a part, forking dichotomously 3 or 4 times; each lobe receives single veins individually.

Remarks

This plant is quite different from *Acrostichopteris* sp. A in the shape and size of lobes. The present specimens also differ from *Acrostichopteris* sp. cf. *A. parvifolia* from the Late Jurassic Oginohama Formation in size and shape of pinnules.

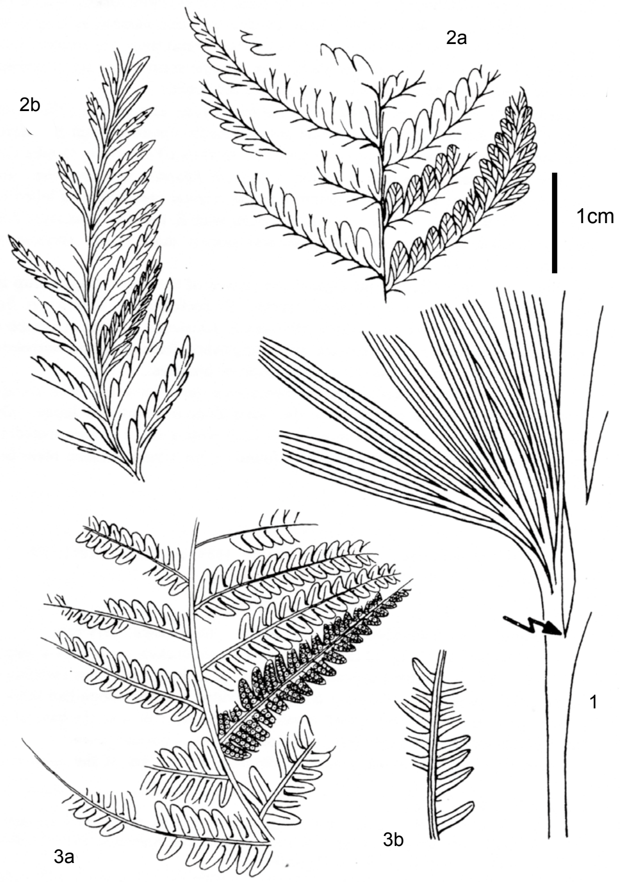


Figure 13. 1. *Acrostichopteris* sp. A. (NSM PP-8240). **2.** *Cladophlebis acutipennis* **2a** (NSM PP-8202), **2b** (NSM PP-8204) **3.** *Cladophlebis* sp. cf. *C. matonioides* **3a** (NSM PP-8211), **3b** (NSM PP-8209), after Kimura and Ohana (1988a)

Form-genus **_Cladophlebis_** Brongniart, 1849

Cladophlebis acutipennis Oishi

Plate VII, 1-3; Figure 13,2

Cladophlebis acutipennis Oishi: Oishi, 1940, p. 249, pl. 9, figs. 4-6 (Lower Cretaceous Yuasa Formation and Upper Monobegawa Group) : Kimura, 1976, p. 190, text-fig. 3 (Lower Cretaceous Yatsushiro Formation) : Kimura and Kansha, 1978a, p. 100, pl. 2, fig. 2; pl. 3, fig. 6; text-fig. 3 (Yuasa Formation): Kimura and Matsukawa, 1979, p. 94, pl. I , fig. 3 ; text-fig. 3 (Lower Cretaceous Sebayashi Formation).

Tyrsopteris sp.: Yokoyama, 1894, p. 213, pl. 23, fig. 3 (Upper Monobegawa Group).

Pecopteris cf. *virginiensis* Fontaine: Yokoyama, 1 894, p. 220, pl. 24, fig. I (ditto).

Material: NSM PP-8201, 8202 (Aratozawa), 8203-8206 (Bunasaka) and 20 other specimens.
Locality: Bunasaka, Kashima Ward, Minamisoma City, Fukushima Prefecture. Aratozawa, Haramachi Ward, Minamisoma City, Fukushima Prefecture.
Strata: Tochikubo Formation (Oxfordian), Somanakamura Group.
Remarks
Sterile fern leaves referable to this species have been known from the Lower Cretaceous plant-beds in the Outer Zone of Japan. No sterile fern leaves referable to this species have not been found from the Upper Jurassic and Lower Cretaceous plant-beds in the Inner Zone of Japan.

Cladophlebis sp. cf. ***C. matonioides*** Oishi
Plate VII, 4-5; Figure 13, 3
Material: NSM PP-8207 (Shidazawaike), 8208 - 8211 (Aratozawa) and 4 other specimens.
Locality: Shidazawaike and Aratozawa, Haramachi Ward, Minamisoma City, Fukushima Prefecture.
Strata: Tochikubo Formation (Oxfordian), Somanakamura Group.
Description
The leaf is at least tripinnate. Main rachis is 2.5 mm wide, sending off closely set first branches at an angle of 70 degrees; the first branch, up to 3 cm wide, but its whole shape unknown. The second branch is long and narrow, typically 2.5 cm long and 4 mm wide, often falcate and sends off 18 pairs of small-sized pinnules katadromically. The pinnules are deltoid to rectangular in form, with obtusely pointed or rounded apex and attached to the wide angle with the expanded base; rectangular pinnule is 4 mm long and 0.5-1 mm wide. The midnerve is distinct, persisting to the tip, but lateral veins are invisible. Three-five pairs of circular reproductive organs (sori?), 0.4 mm in diameter, are disposed superficially on both sides of the midnerve, but their details are uncertain. (Original description in Kimura and Ohana, 1988a)

Remarks
Present pinnules resemble closely in form those of *Cladophlebis matonioides* originally described by Oishi (1940) possibly from the Oginohama and Mone Formations on the basis of sterile leaves. However, as pinnules of present specimens are far smaller than those of *Cladophlebis matonioides*, so present specimens are regard as leaves of C. sp. cf. C. matonioides. The pinna fragments resemble those of *Matonidium* ex gr. *goepperti* described in this paper, but the leaves are distinguished from those of the latter by their obviously tripinnate habit instead of pedatifid leaves of the latter.

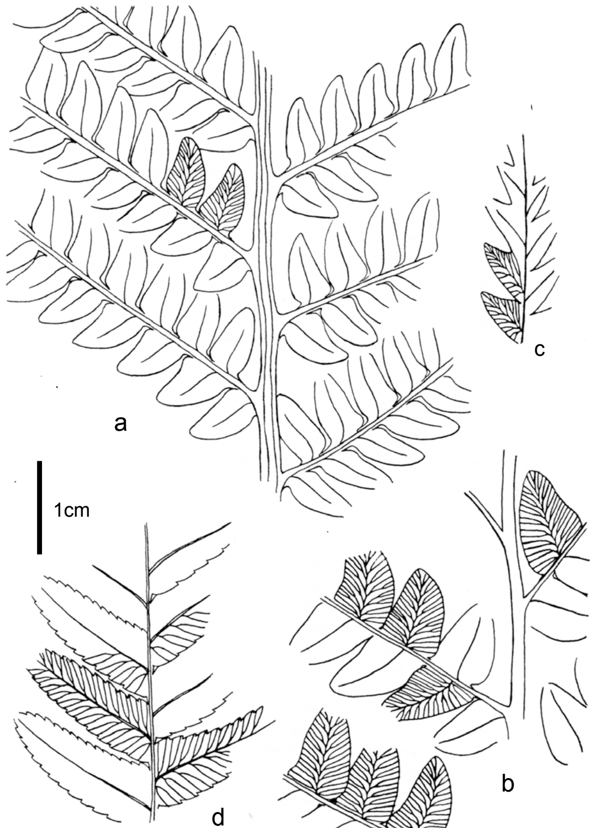


Figure 14. *Cladophlebis* sp. cf. *C. virginiensis*
a. (NSM PP-82028228), **b.** (NSM PP-8221), **c.** (NSM PP-828224), **d**. (NSM PP-8219). after Kimura and Ohana (1988a)

Cladophlebis sp. cf. ***C. virginiensis*** Fontaine
Plate VIII, 1-3; Figure 14
Material: NSM PP-8212 (Bunasaka), 8213-8229 (Aratozawa) and 99 other specimens.

Locality: Bunasaka, Kashima Ward, Minamisoma City, Fukushima Prefecture.
Aratozawa, Haramachi Ward, Minamisoma City, Fukushima Prefecture.
Strata: Tochikubo Formation (Oxfordian), Somanakamura Group.
Description
Obtained are all sterile bipinnate leaf-fragments. Of these, a leaf shown in Plate VIII, 3 is the largest fragment. Rachis is rather thick, 3 mm wide below with a median furrow on its upper surface, sending off katadromically long, narrow and nearly parallel-sided pinnae typically at an angle of 50 degrees, 9.5 cm long and 1 .6 cm wide at the middle, and bearing 1 8-20 pairs of pinnules at a wide angle to the pinna axis. Pinnules are closely set and variable in form according to the position on a leaf; deltoid in form on the distal half of a leaf and elongated-deltoid on the proximal half of a leaf. In deltoid pinnules, margins are entire; acroscopic basal margin is rather markedly constricted and basiscopic basal margin slightly constricted, then decurrent; midnerve is distinct, persisting to the obtusely pointed apex and sends off 7 pairs of mostly once forked lateral veins obliquely. Elongate-deltoid pinnules are attached to the pinna axis by the whole base; margins are shallowly serrate, with obtusely pointed apex ; midnerve sends off 11-12 pairs of once forked lateral veins obliquely; each serration receives a set of lateral vein. (Original description in Kimura and Ohana, 1988a)
Remarks
Present leaves resemble closely those of *Cladophlebis virginiensis* Fontaine and its allied species (see Berry, 1911, pp. 248-249; Bell, 1956, p. 50) known from the Lower Cretaceous of North America in form and venation of pinnules. In some leaves of *Cladophlebis virginiensis* (e.g. *C. virginiensis* forma acuta, by Bell, 1956), basiscopic basal pinnules are broader and bilobed (Bell's pl. 5, fig. 1). No such specialized pinnules have been found in present collection. Therefore, I reserve to identify our leaves fully with those of *Cladophlebis virginiensis*. In all specimens examined, pinnules appear to be coriaceous and their upper surface is mostly convex and their margins are sometimes reflexed.

Cladophlebis **sp. A**

Material: NSM PP-8230 - 8234 (Aratozawa) and other 21 specimens.
Locality: Aratozawa, Haramachi Ward, Minamisoma City, Fukushima Prefecture.
Strata: Tochikubo Formation (Oxfordian), Somanakamura Group.
Description
Obtained leaves are all sterile, tripinnate and medium-sized, but their whole shape and size are unknown. Ultimate pinnae are set rather closely, at least 5 cm long and 0.7 cm wide, attached nearly perpendicularly to the comparatively thick penultimate pinna axis (4 mm wide basally) and send off katadromically 23-25 pairs of pinnules. Pinnules are small-sized, rectangular in form with obtusely pointed apex and expanded base, attached by their whole base to the pinna axis at a wide angle, but angle is reduced distally, typically 5 mm long and up to 1.5 mm wide and with obtusely pointed apex; margins are entire. The pinnules of basal pair often longer than the rest. Midnerve is rather distinct, persisting to the tip and sends off 7 pairs of once forked lateral veins. (Original description in Kimura and Ohana, 1988a)
Remarks
Present leaves are characterized by having small-sized pinnules which are rectangular in form with obtusely pointed apex and with once forked lateral veins. Present leaves are most close to those illustrated by Yokoyama (1894) as *Pecopteris browniana* Dunker from the Lower Cretaceous plant-beds in the Outer Zone of Southwest Japan. But Yokoyama's Ieaves seem to be different from present leaves in their pinnules, according to Yokoyama (1894), sometimes with twice to thrice forked lateral veins. The sterile pinnules of *Polypodites*

verestchaginii originally described by Krassilov (1967) from the Lower Cretaceous of Southern Primorye resemble those of ours in form, size and venation.

Cladophlebis sp. B

Material: NSM PP-8235-8239 (Bunasaka).

Locality: Bunasaka, Kashima Ward, Minamisoma City, Fukushima Prefecture.

Strata: Tochikubo Formation (Oxfordian), Somanakamura Group.

Description

Obtained are only five fertile pinna fragments of which pinnules are rectangular in form, 1 cm long and 3 mm wide, with obtusely pointed apex and decurrent base, attached to the slender pinna axis at an angle of 60 degrees, and divided katadromically into 6-7 pairs of shallow lobes. Midnerve is distinct, not straight but zigzag in course, persiting to the tip, and sends off single or once forked lateral veins; each lobe receives a set of lateral vein, but the lateral veins do not reach the tip of each lobe. Fructification is semi-circular in surface view, up to 1 mm in diameter, superficial, and each terminating the lateral veins; details of the fructification are not known. (Original description in Kimura and Ohana, 1988a)

Remarks

Owing to the uncertainty of my fructification, it is difficult to ascertain the taxonomic position of the leaves. Therefore, unavoidably I at present regard our leaves as *Cladophlebs* sp. B. Externally our pinnules resemble those of *Polypodites polysorus* Prynada described by Krassilov (1967) from the Lower Cretaceous of Southern Primorye. The pinnules of *Cladophlebis* sp. B also resemble those of *Dicksoniopteris naumanni* originally described by Nathorst (1890) and later by Yokoyama (1894) from the Lower Cretaceous plant-beds in the Outer Zone of Southwest Japan. Oishi (1939, 1 940) regarded Nathorst's and Yokoyama's leaves as Klukia yokoyamae.

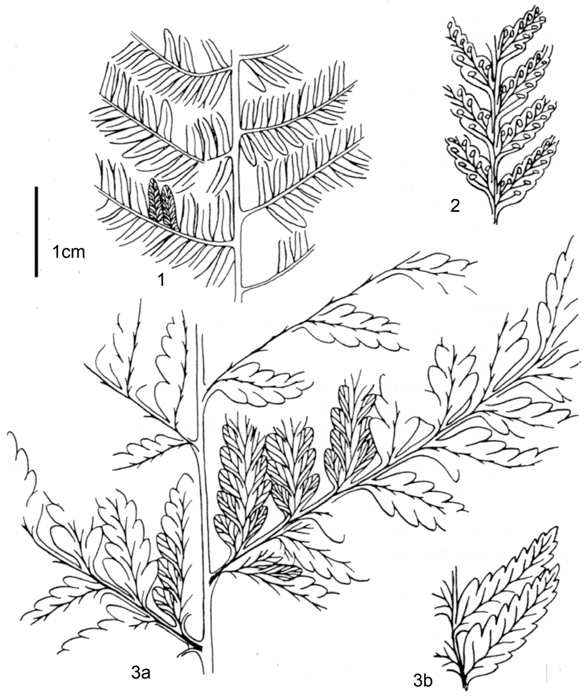


Figure 15. 1. *Cladophlebis* sp. A (NSM PP-8232) **2.** *Cladophlebis* sp. B (NSM PP-8236) **3.** *Sphenopteris elegans.* **3a** (NSM PP-8192, 8196). **3b** (NSM PP-8196) after Kimura and Ohana (1988b)

Form-genus ***Sphenopteris*** Sternberg, 1825

Sphenopteris elegans (Yokoyama) Oishi

Plate IX

Onychiopsis elegans Yokoyama: Yokoyama, 1894, p. 215, pl. 28, fig. 7, 7a (Kaiseki-yama; Lower Cretaceous Ryoseki Formation).

Sphenopteris elegans (Yokoyama) Oishi: Oishi, 1940, p. 236, pl. 8, fig. I (Otani; ditto), figs. 2-3 (Zusahara; possibly Tochikubo Formation).

Material: NSM PP-8191 (Aratozawa), 8192-8200 (Bunasaka) and 13 other specimens.

Locality: Bunasaka, Kashima Ward, Minamisoma City, Fukushima Prefecture. Aratozawa, Haramachi Ward, Minamisoma City, Fukushima Prefecture.

Strata: Tochikubo Formation (Oxfordian), Somanakamura Group.

Emended diagnosis

Leaf sterile and bipinnate. Rachis slender, 1 mm wide with a median furrow above, sending off pinnae at an angle of 60 degrees katadromically (Whole leaf unknown.). Pinnae set closely, overlapping each other laterally, elongate-triangular, 10 cm long or more and 3 cm wide at the middle portion of a leaf, with acuminated apex, and bearing 16 pairs of katadromically ordered pinnules. Pinnules ovate or elongate-ovate in form, medium-sized, typically I .5 cm long and up to 0.5 cm wide, with obtusely pointed apex, divided shallowly into 5-7 pairs of lobes, but occasionally with entire margins, markedly contracted near the base, then some-times decurrent, and attached to the very slender pinna axis at an angle of 60 degrees, but the angle increased towards the pinna base. Pinnules on the proximal region of a leaf sometimes longer with deeply divided lobes looking like small-sized pinnules with entire margins. Midnerve distinct, persisting to the tip, and sending off sympodially disposed lateral veins; each lateral vein further sending off simple secondary lateral vein, but basal ones sometimes once forked; each lobe receiving a set of lateral vein.

Remarks

Sphenopteris elegans was originally described by Yokoyama (1894) as *Onychiopsis elegans* on the basis of a single sterile pinna fragment from the Ryoseki Formation, and later revised by Oishi (1940) as *Sphenopteris elegans* on the basis of his additional ill-preserved material both from the Ryoseki and possibly from the Tochikubo Formations. Present leaves were preserved rather well, Kimura and Ohana (1988a) give the above-mentioned emended diagnosis of this species. Yokoyama (1894) mentioned that the pinnules were with entire margins in the proximal half and with corsely-toothed margins in the apical half, and with obtusely pointed apex. But in present leaves, they show the pinnules divided into shallow lobes throughout as well as those of Oishi's specimens. *Sphenopteris elegans* is characterized by its shallowly lobed pinnules with a marked midnerve sending off sympodially disposed lateral veins. As a number of fern or fern-like leaves with similarly looked sterile pinnules have been recorded from the Upper Paleozoic and Mesozoic plant-beds under the non-committal generic name *Sphenopteris*, it is fairly difficult to make the precise comparison of the present species with those *Sphenopteris* species. The pinnules of *Sphenopteris elegans* resemble some sterile pinnules of *Coniopteris burejensis* (Zalessky) Seward, but in the latter species, pinnules and their lobes are much directed forwards.

(emended diagnosis and remarks from Kimura and Ohana, 1988a)

Bennettitales

Williamsoniaceae

Genus ***Otozamites*** F. W. Braun, 1842

Otozamites sp. cf. ***O. kondoi*** Oishi

Plate X, 1-2; Figure 16

Material: NSM PP-8242 (Fukounonakayama-rindo), 8243 (Okushidazawa), 8244 (Aratozawa), N201200020, N201200296 (Shidazawa).

Locality: Fukounonakayama-rindo, Aratozawa. Okushidazawa, and Shidazawa, Haramachi Ward, Minamisoma City, Fukushima Prefecture.

Strata: Tochikubo Formation (Oxfordian), Somanakamura Group.

Description

One specimen that two pinnae attached to the rachis was obtained. Other specimens are small-sized detached pinnae. The rachis is 0.3 cm thick, pinnae probably alternate. The pinnae are oblong in outline, 2.3 cm long and 0.9-1.3 cm wide, with rather rounded asymmetrical base, but not auriculated; veins are originated from the central area of pinna base, then radiating, forking dichotomously at all levels, and mostly ending at lateral margins; density is 24 per cm at the distal part of pinna. (Original description in Kimura and Ohana, 1988a)

Remarks

Present specimens' pinnae are characterized by being not conspicuously auriculated ones and thus are close to those of *Otozamites kondoi* originally described by Oishi (1940) from the Upper Jurassic Shishiori Group. But at present we reserve to make full identity of the pinnae with those of Oishi's species because the present specimens are fragmentary fossils.

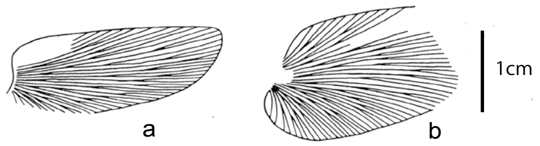


Fig. 16. *Otozamites kondoi* **a** (NSM PP-8243). **b** (NSM PP-8242) after Kimura and Ohana (1988b).

Genus ***Zamites*** Brongniart, 1828

Zamites brevipennis (Oishi) Takimoto, Ohana and Kimura

Plate X, 3; Figure 17

Material:KHFM-210023, KHFM-210024.

Locality: Kitanoiri, Kashima Ward, Minamisoma City, Fukushima Prefecture.

Strata: Tochikubo Formation (Oxfordian), Somanakamura Group.

Description

The leaf looks flexible and is elongate, pinnate, more than 14.5 cm long and 5 cm wide distally and 3.5 cm wide proximally. Distal pinnae are oblong, 5 cm long and 1.6 cm wide. The acroscopic margin is nearly straight while the basiscopic margin is curved and rounded distally, forming obtusely pointed apex. The pinna base is not expanded but slightly contracted. Pinnae are set closely and attached alternately by crescent-shaped base to the upper sides of the slender rachis at a wide angle. Proximal pinnae are elongate-oblong in form and smaller in size, 4 cm long and 0.7 cm wide. Crowded veins originate from crescent base, forking dichotomously on the proximal portion, then radiate to the margins, but do not anastomose; proximal density is 19 per cm and distal density is 24 per cm. (Original description in Kimura and Ohana, 1988a)

Discussion and comparison

It is difficult to distinguish bennettitalean *Zamites* from cycadalean *Pseudoctenis* on the basis of external morphology. Emended diagnosis of the genus *Pseudoctenis* was given by Harris (1964). Harris's diagnosis based on the external morphology as follows: 1) pinnae broad or narrow, 2) pinnae elongate-lanceolate or parallel-sided, 3) pinna apex truncates or contracted, 4) pinna base expanded or contracted, 5) veins numerous, parallel, simple or forked.

These diagnostic features are applicable to the leaves

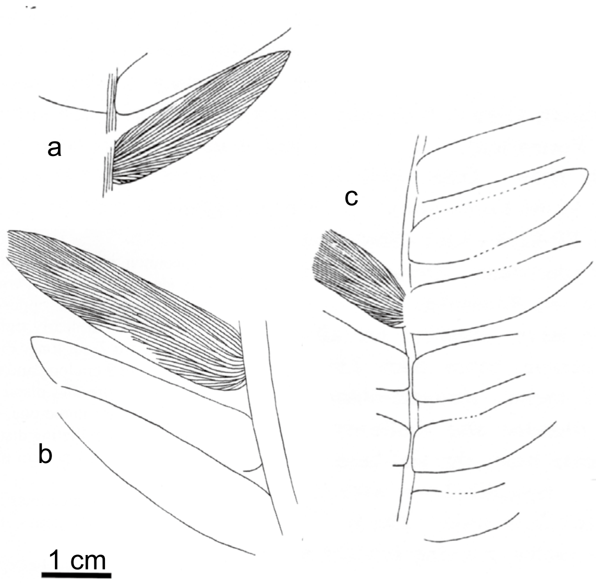


Figure 17 *Zamites brevipennis*. **a.** (NSM PP-8295). **b.** (KHFM-210023). **c.** (NSM PP-8294) after Takimoto et al. (2008)

of *Zamites*-type and *Pseudoctenis*-type plants. Under the circumstances, it is doubtful that Oishi's leaves without preserved cuticle really belong to *Pseudoctenis*.

The present leaf is characterized by oblong pinnae attached to the upper side of a slender rachis with slightly contracted and crescent bases. We were of the opinion that the present leaf is a bennettitalean, because in cycadalean leaf, so far as I know, no crecent-shaped base has been found except for *Nilssonia* leaves. Some species of extant cycads have pinnae of crescent-shaped base, however, Mesozoic cycads except *Nilssonia* do not have pinnae of crescent-shaped base.

Similar leaves were first described by Oishi (1940) from the Tochikubo Formation as *Pseudoctenis brevipennis*. We consider Oishi's leaves are not cycadalean *Pseudoctenis* but these are bennettitalean *Zamites*. Therefore, Takimoto et al. (2008) proposed a new combination as *Zamites brevipennis* (Oishi) comb. nov.

Zamites nipponicus Kimura et Ohana

Plate X, 4 and XI; Figure 18

Matenal: Holotype: NSM PP-8245 (Bunasaka). NSM PP-8246, 8252, 8253, 8254 (ditto). *Examined specimens*; NSM PP-8247 - 8251 and 120 other specimens.

Locality: Bunasaka, Kashima Ward, Minamisoma City, Fukushima Prefecture. Shidazawakita, Haramachi Ward, Minamisoma City, Fukushima Prefecture.

Strata: Tochikubo Formation (Oxfordian), Somanakamura Group.

Description

Leaf medium-sized, elongate-oblanceolate in outline, 20-30 cm long and 7-15 cm wide with rather slender rachis, 3.5 mm wide below. Petioles are at least 2 cm long, gradually thicker to the base. Pinnae long and narrow, elongate-lanceolate in outline, but the length varying according to the position of a leaf. Pinnae alternate, set rather remotely, attached to the upper sides of rachis at an angle of 60 degrees at the middle portion of a leaf, but angle reduced at both ends, asymmetrically contracted and rounded at base, sometimes acroscopic base markedly contracted and rounded, and gradually narrowing to the acuminate apex; the longest pinna 9 cm long and up to 7.5 mm wide and the shortest one 1.3 cm long and up to 3 mm wide. Veins numerous, originating at narrow base, dichotomously forking near the base, then running parallel and ending at the margins of apical half of pinna, not converging at apex; typically 11 in number at base and 18-20 in number (25 per cm in density) at the middle. (Original description in Kimura and Ohana, 1988a)

Comparison and discussion:

The leaves belong undoubtedly to *Zamites*, because of the pinnae with asymmetrically contracted and rounded base attached to the upper sides of rachis. *Zamites nipponicus* is characterized by its medium-sized elongate-oblanceolate leaf bearing elongate-1anceolate pinnae with acuminate apex and crowded veins. This plant was first described by Oishi (1940) probably from the Tochikubo Formation as cf. *Zamites feneonis* Brongniart. In fact *Zamites nipponicus* resembles most closely *Z. feneonis* (Brongniart) Unger illustrated by Ettingshausen (1852), Schimper (1872) and other authors mainly from the Upper Jurassic-Lower Cretaceous of Europe. But *Zamites feneonis* is barely distin-

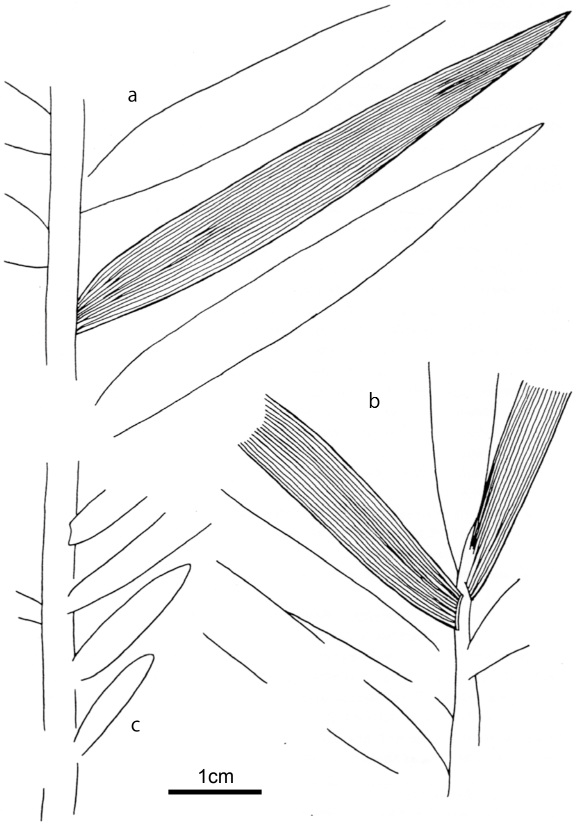


Figure 18. *Zamites nipponicus* **a Holotype** (NSM PP-8245) . **b** (NSM PP-8247). **c Paratype** (NSM PP-8254) after Kimura and Ohana (1988b)

guished by its pinnae attached to the rachis at a wide angle, with symmetrically contracted base and with less crowded veins. *Zamites nipponicus* also resembles in pinna form the following *Zamites* species: *Zamites hoheneggeri* (Schenk) Li: Sze et al., 1963; formerly regarded as *Podozamites hoheneggeri* Schenk (Schenk, 1869) and as *Glossozamites hoheneggeri* (Schenk) (Yokoyama, 1906) : Middle-Upper Jurassic of Sichuan, China. *Z. corrugatus* Prynada described by Stanislavsky (1971): Upper Triassic of Donbass. *Z. ivanovii* Kryshtofovich et Prynada (Samylina, 1961) or *Zamiophyllum ivanovii* (Kryshtofovich et Prynada) (Krassilov, 1967): Lower Cretaceous of Southern Primorye . *Z. vachrameevii* Doludenko: Doludenko and Svanidge (1969) : Upper Jurassic of Georgia. *Z. recta* (Tate) Seward: Redescribed by Anderson and Anderson (1985) : Lower Cretaceous of South Africa. However, *Zamites hoheneggeri* is distinguished by its pinnae attached to the rachis at right angle, with markedly contracted base and with small number of veins (15 in each pinna), *Z. corrugatus* by its broader and shorter pinnae, *Z. ivanovii* by its closely set and rather broader pinnae with suddenly narrowed distal end, *Z. vachrameevii* by its narrower pinnae with not so contracted base and *Z. recta* by its far longer pinnae (nearly twice as long as those of *Z. nipponicus*).

The leaves of *Zamites varius* described by Kimura and Ohana (1987b) from the Middle Jurassic Utano Formation, Japan also resemble in pinna form those of *Z. nipponicus*, but in the former species the pinnae are shorter and thick and with small number of veins (l0 per cm in density). A broken leaf regarded by Oyama (1954) as *Glossozamites* cf. *hoheneggeri* from the Upper Jurassic Oginohama Formation may belong to *Zamites nipponicus*.

Recently, a lot of fossils of *Zamites nipponicus* occurred under the construction of Joban highway. Very important specimens are included in these fossils, for example, some leaves attached to the stem and complete whole leaf. I will try to reconstruct whole plant of *Zamites nipponicus* near feature.

Genus ***Ptilophyllum*** Morris, 1840

Ptilophyllum jurassicum Kimura et Ohana

Plate XII; Figure 19

Material: Holotype; NSM PP-8260 (Shidazawaike). Paratypes ; NSM PP-8258, 8259, 8260 (ditto). Examined specimens ; NSM PP-8261-8285 and 54 other specimens.

Locality: Shidazawaike. Okushidazawa, Haramachi Ward, Minamisoma City, Fukushima Prefecture.

Strata: Tochikubo Formation (Oxfordian), Somanakamura Group.

Diagnosis

Leaf medium-sized, more than 14cm long and up to 6 cm wide. (Whole leaf unknown.) Rachis rather thin in the middle part of a leaf, 2 mm wide, but becoming thicker to the petiole, up to 4 mm wide, sending alternately or suboppositely off closely set pinnae at an angle of 75 degrees from the upper sides of rachis; angle reduced apically. Pinnae long and narrow, straight, parallel-sided for the most part, narrowing abruptly to the obtusely pointed apex; both acroscopic and basiscopic basal margins straight, but sometimes acroscopic basal angle slightly rounded; typically 3 cm long and up to 5 mm wide at base; pinnae on the proximal part becoming shorter. Veins originated from whole of base, simple, running in parallel, not converging at apex, typically 15 in number in each pinna (50 per cm in density), but 13 in the proximal pinnae. (Reproductive organs not known.) (Original description in Kimura and Ohana, 1988b)

Discussion and comparison

Kimura and Ohana (1998b) established *Ptilophyllum jurassicum* as a new species on the basis of numerous specimens derived from the Tochikubo Formation.

Ptilophyllum .jurassicum is characterized by its medium-sized leaf bearing long and narrow pinnae of which the ratio of L/W is typically 5.8-(6.3)-6.8, but it is 4.7~6.4)-(9.5) in the apical pinnae (Figure 19, c) and 2.4-(4.5)-6.0 in the proximal pinnae (Figure 19, b). *Ptilophyllum jurassicum* is close to *P. oshikaense* (Kimura and Ohana, 1989b), but differs from *P. oshikaense* bearing more shorter and elongate-triangular pmnae.

Oishi (1940) described a *Ptilophyllum* leaf as *P. pecten* (Phillips) (his pl. 35, fig. 3) from Kami-Mano-mura (possibly from the Tochikubo Formation). It agrees well with our *Ptilophyllum jurassicum*. So far as the emended diagnosis and illustrations of *Ptilophyllum pecten* given by Harris (1969) on the basis of the leaves from the Middle Jurassic of Yorkshire are

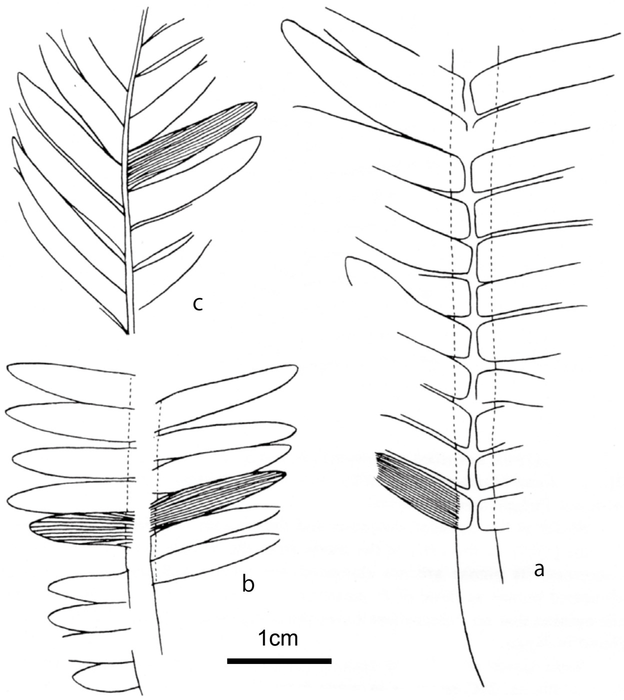


Figure 19. *Ptilophyllum jurassicum* **a.** (NSM PP-8261). **b.** Paratype (NSM PP-8259). **c.** (NSM PP-8268) after Kimura and Ohana (1988b)

concerned, its pinnae are not elongated but shorter and small-sized, and no such elongated pinnae as those of *P. jurassicum* are shown in his illustrations. Some leaves regarded by Harris (1969) as *Ptilophyllum pectinoides* (Phillips), such as his fig. 26C resemble in pinna form and size those of *P. jurassicum*, but the former is distinguished by its gradually narrowing pinnae with small number of veins (8 in number in each pinna). cf. *Ptilophyllum* sp. A described by Person and Delevoryas (1982) from the Middle Jurassic of Oaxaca, Mexico resembles in external leaf-form and size of *P. jurassicum*.

Recently, a lot of fossils of *Ptilophyllum jurassicum* occurred under the construction of Joban highway. Very important specimens are included in these fossils, for example, some leaves attached to the stem and all part of a leaf. I will try to reconstruct whole plant of *Ptilophyllum jurassicum* near feature.

Ptilophyllum linearifolium Kimura et Ohana

Plate XIII, 1-3

Material: N201200025, 201200043, 201200061, 201200072, 201200096, 201200104, and 201200106.

Locality: Shidazawa. Haramachi Ward, Minamisoma City, Fukushima Prefecture.

Strata: Tochikubo Formation (Oxfordian), Somanakamura Group.

Description

Leaf pinnate, more than 14cm long and up to 6 cm wide. Rachis rather thin in the middle part of a leaf, 2 mm wide, but becoming wide below up to 3 mm. Pinnae set rather remotely, linear, and attached to the upper surface of rachis nearly perpendicularly. Pinnae on the middle part of a leaf typically 2.2 cm long and 2 mm wide, gradually narrowed to the obtusely pointed apex. Veins 6-8 in numbers in each pinna running in parallel,

Remarls

Kimura and Ohana (1989b) established *Ptilophyllum linearifolium* based on the specimens from the Lower Cretaceous Monobegawa Formation, Kochi Prefecture. This species also found from the Upper Jurassic Mone Formation, Miyagi Prefecture, They are in the Outer Zone of Southwest and Northeast Japan

Ptilophyllum sp. cf. ***oshikaense*** Kimura et Ohana

Plate XIII, 4

Material: N201200056

Locality: Shidazawa. Haramachi Ward, Minamisoma City, Fukushima Prefecture.

Strata: Tochikubo Formation (Oxfordian), Somanakamura Group.

Description

Leaf pinnate, rather small-sized, elongated, parallel-sided for the most part, gradually narrowed towards both ends and with thick petiole, more than 14cm long and up to 5cm wide. Pinnae alternate, closely set subulate in form, rounded apex, and attached to the upper surface of slender rachis. Veins simple, running in parallel, 10-13 in number.

Remarks

Ptilophyllum oshikaense is very close to *P, jurassicum* originally described from the Tochikubo Formation, however they are distinguished by its obliquely set pinnae narrowing gradually towards the obtusely pointed or rounded apex.

Ptilophyllum sp. F

Pl. XIV, 1; Figure 20

Material: NSM PP-8286-8288 (Aratozawa).

Locality: Aratozawa. Haramachi Ward, Minamisoma City, Fukushima Prefecture.

Strata: Tochikubo Formation (Oxfordian), Somanakamura Group.

Description

Obtained are only three leaf-fragments. Of these, the largest leaf-fragment preserved more or less twisty. The leaf is large-sized, more than 12cm wide, with comparatively thick rachis, 3.5mm wide. The pinnae are set closely, attached to the upper sides of rachis at an angle of about 70 degrees, long and narrow, up to 6.5 cm long, nearly parallel-sided for the most part, typically 3.5 mm wide, then narrowing gradually towards the acutely pointed apex. Pinna base is asymmetric; its basiscopic basal margin is slightly decurrent and acroscopic one contracted and forming a round angle, but not forming an auricle. The veins arise from whole region of attachment, simple, parallel, ending near the apex; typically 7 in number in each pinna. Reproductive organs are not known. (Original description in Kimura and Ohana, 1988b)

Remarks

Kimura and Ohana (1988b) assigned the leaves to *Ptilophyllum* because their pinnae are attached to the upper sides of rachis and the basiscopic basal margin of pinna, although not so marked, decurrent and acroscopic one is contracted and rounded. *Ptilophyllum* sp. F is characterized by its large-sized leaf bearing long and narrow pinnae. Among various *Ptilophyllum* species hitherto described, most close is cf. P. acutifolium Morris described by Person and Delevoryas (1982) from the Middle Jurassic of Oaxaca, Mexico. They included the large-sized leaves from Veracruz

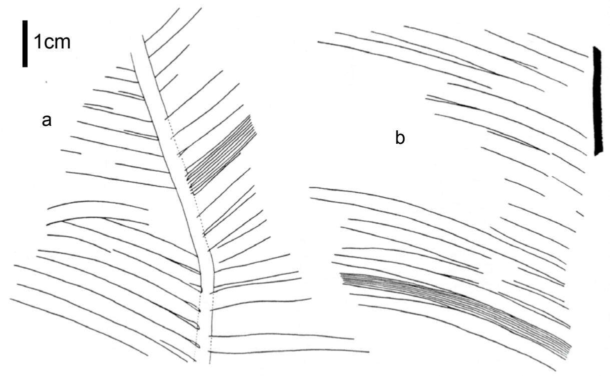


Figure 20. *Ptilophyllum* sp. F **a** (NSM PP-8287). **b** (NSM PP-8288). after Kimura and Ohana, (1988b).

regarded by Wieland (19l4~l6) as *Ptilophyllum acutlfolium* var. *maximum* into their cf. *P. acutifolium*. The broadest Mexican leaf is up to 8.5 cm wide and veins are typically 12 in number in each pinna. But present leaves are distinguished from the Mexican leaves by far larger size and small number of veins in each pinna. *Ptilophyllum acutifolium* var. *maximum* described by Feistmantel (1877, p. 1 17, pl. 40, figs. 1-5) from Rajmahal Hills is also similar in leaf-form and is characterized by its large-sized leaves, but is distinguished by its narrower leaves (8 cm wide) than ours and its pinnae with markedly decurrent base and rounded acroscopic basal angle. Bose and Kasat (1972) regarded Feistmantel's Variety as *Ptilophyllum acutifolium* and illustrated one leaf as the largest one so far collected from India (their fig. 115). According to their emended diagnosis given to *Ptilophyllum acutlfolium*, the leaf-width is 4~l0.5cm. Thus, present leaves are far broader than those of Indian *Ptilophyllum acutifolium*.

Ptilophyllum sp. G

Pl. XII, 4; Figure 21, 1

Material: NSM PP-8289 (Aratozawa), N201200237 (Shidazawa).

Locality: Aratozawa and Shidazawa. Haramachi Ward,

Minamisoma City, Fukushima Prefecture.
Strata: Tochikubo Formation (Oxfordian), Somanakamura Group.
Description
The leaf is small-sized, about 2.2 cm wide, nearly parallel side. Pinnae are set closely, attached to the upper sides of rachis at an angle of about 65 degrees, typically 1.2 cm long, 2.5 mm wide for the most part, and with rounded apex. Pinna base is asymmetric; its basiscopic basal margin is slightly decurrent and acroscopic one straight or slightly contracted. Veins are 9 in number in each pinna, simple, running parallel. (Original description in Kimura and Ohana, 1988b)
Remarks
Ptilophyllum sp. G resembles in pinna form and size with *P. cuchense* Morris, however is distinguished by its venation.

***Ptilophyllum* sp. H**
Figure 21, 2
Material: NSM PP-8290- 8293(Umenokizawa)
Locality: Umenokizawa. Kashima Ward, Minamisoma City, Fukushima Prefecture.
Strata: Tochikubo Formation (Oxfordian), Somanakamura Group.
Description
The Pinnae are attached suboppositely and perpendicularly to the upper sides of rachis by whole base, closely set, rectangular in form; pinna apex is obliquely trucated or rounded and is neither auriculate nor decurrent at base. The veins are 13 in number at pinna base, then radiating and forking once or rarely twice. (Original description in Kimura and Ohana, 1988b)
Remarks
Ptilophyllum sp. H resembles in pinna form and size with *P. hirsutum* Thomas and Bancroft, without decurrent base and venation.

Genus ***Nipponoptilophyllum*** Kimura et Tsujii, 1984
Nipponoptilophyllum bipinnatum Kimura et Tsujii
Plate XIV, 3-4; Figure 21, 3
Material: NSM PP-8399. NSM PP-8400 - 8406
Examined specimens: NSM PP-8407 - 8418 and 30

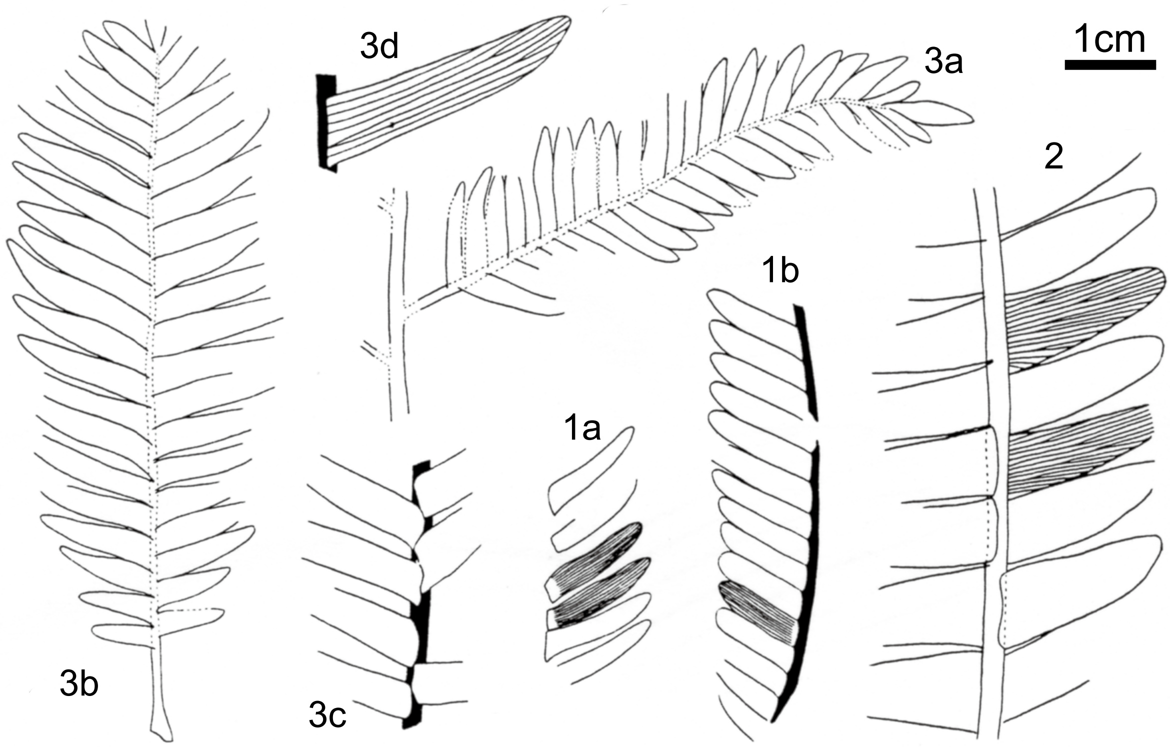


Figure 21. 1. *Ptilophyllum* sp. G. a,b (NSM PP-8289). **2.** *Ptilophyllum* sp. H (NSM PP-8290) **3.** *Nipponoptilophyllum bipinnatum*. **a,b,d** (NSM PP-8399, Holotype). **c.** (NSM PP-8401) after Kimura and Ohana (1988b)

other specimens.
Locality: Aratozawa . Haramachi Ward, Minamisoma City, Fukushima Prefecture.
Strata: Tochikubo Formation (Oxfordian), Somanakamura Group.
Remarks
This species is represented by the leaves of bipinnate habit and is characterized by the elongate-oblanceolate or elongate-obovate penultimate pinnae. The forms of the penultimate and ultimate pinnae are unique and are different from the leaves and pinnae of other *Ptilophyllum* species known in Japan. Detailed description of this species was already made by Kimura and Tsujii (1984). The second *Nipponoptilophyllum* species was found from the Lower Cretaceous Monobe Formation, Kochi Prefecture.

Genus ***Williamsonia*** Carruthers, 1870
Williamsonia sp.

Plate XIV, 4
Material: KHFM-210025, 210026 (counter part).
Locality:Oyama (Figure 1-2), Kashima Ward, Minamisoma City, Fukushima Prefecture.
Strata: Tomizawa Formation (Tithonian), Somanakamura Group.
Description
A single bennettitalean female reproductive organ was found. This reproductive organ is longitudinally deltoid in form, at least 7 cm long and 7 cm wide at middle, densely covered with bracts that are narrow, nearly converging at apex. Unfortunately, the proximal part is crushed and the receptacle is uncertain.
Remarks
A similar female reproductive organ (or fruit) was recorded from the Upper Jurassic Oginohama Formation of the Oshika Group exposed in the further north of the Somanakamura Group (Kimura and Ohana, 1989a, b). Unfortunately, the inside of this reproductive organ is not preserved. Accordingly, I cannot give a specific epithet. (Takimoto et al., 2008)

Class Cycadopsida
Order Cyoadales
Genus ***Pseudoctenis*** Seward, 1911
Pseudoctenis sp. A
Plate XV, 1; Figure 22

Material: NSM PP-8296, 8297 (counterpart of 8296).
Locallity: Aratozawa Haramachi Ward, Minamisoma City, Fukushima Prefecture.
Strata: Tochikubo Formation (Oxfordian), Somanakamura Group.
Description
Obtained is a single leaf-fragment, which is thought to be an apical portion of leaf with 7 subopposite pairs of pinnae incompletely preserved. Pinnae are rather remotely set, attached to the lateral sides of slender axis at an angle of 55 degrees, but angle reducing apically. Pinna form is uncertain, because pinna apices are all missing, but pinnae are narrowed gradually towards the base and decurrent; maximum pinna width preserved is 5 mm. Veins are prominent, 5 in number at base; forking dichotomously and running in parallel, l0-11 in number at the preserved tip. (Original description in Kimura and Ohana, 1988b)

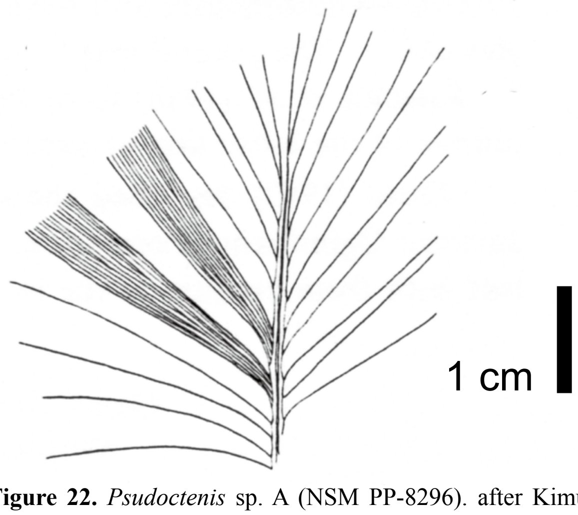


Figure 22. *Psudoctenis* sp. A (NSM PP-8296). after Kimura and Ohana (1988b)

Remarks
The general feature of the leaf resembles that of *Pseudoctenis* sp. described by Kimura et al. (1986)

from the upper Liassic Nishinakayama Formation, but the pinnae of the latter are far narrower. Oishi (1940) described the leaves as *Pseudoctenis lanei* Thomas from the Upper Jurassic Oginohama Formation, but it is difficult to make detailed comparison of the leaf with them because of the incompleteness of the pinnae. Recently, quite similar specimen of this species collected by a local collector from the Tochikubo Formation, however little different in strong three veins.

Family Nilssoniaceae Kimura and Sekido, 1975

Genus ***Nilssonia*** Brongniart, 1825

Nilssonia sp. cf. ***N. canadensis*** Bell

Plate XV, 2; Figure 23

Nilssonia orientalis Heer: Nathorst, 1890, p. 5, pl. I , figs.' 4-5 (Lower Cretace-ous Ryoseki Formation).

Nilssonia orientalis Heer : Oishi, 1940, p. 307 (pars), pl. 26, figs. 2-3 (Upper Jurassic Kogoshio or Mon6 Formation).

Material: SDS'05-64, 105, 543 (Shidazawaike), NSM PP-8298-8301 (Shidazawaike), 8302 (Aratozawa), 8303 (Okushidazawa) and 35 other specimens.

Locality: Shidasawaike, Okushidazawa and Aratozawa, Haramachi Ward, Minamisoma City, Fukushima Prefecture. Bunasaka, Kashima Ward, Minamisoma City, Fukushima Prefecture.

Strata: Tochikubo Formation (Oxfordian), Somanakamura Group.

Description

The leaves obtained are all detached and broken, variable in size and with long petiole, more than 5 cm long. The lamina covers completely upper surface of rachis, elongate-oblong in form, abruptly narrowing towards the broadly rounded and shallowly notched apex, contracting to the rotund or narrowly cuneate base; the leaf-base is slightly asymmetric; margins are entire. The rachis is thick, typically 2 mm wide. The largest leaf is up to 4.9 cm wide and the smallest one is 1.2 cm wide. The veins are simple; nearly perpendicular or about 80 degrees to the rachis, running straight to the margin or slightly curved upwards near the margin. The vein-density is variable according to the leaf or to position on the same leaf, 11-40 per cm; generally denser in smaller leaves and coarser in larger ones.

Remarks

None of the specimens is complete, but a few show their base and apex. Present leaves are specifically most close to those of *Nilssonia canadensis* originally described by Bell (1956) from the Lower Cretaceous of Western Canada. But Kimura and Ohana (1988b) indicated that they don't fully agree with Bell's original leaves as follows: l) Bell's rachises are more thicker (up to 4 mm wide). 2) In Bell's leaves, their apices are bluntly pointed or narrowly rounded. 3) In Bell's leaves, the vein-density is 10-18 per cm and the occasional veins are forked at their origin or on the course to the margin. Under the circumstances, they regard the leaves as *Nilssonia* sp. cf. *N. canadensis* Bell. Oishi (1940) described similar leaves as *Nilssonia orientalis* Heer from the Upper Jurassic Kogoshio or Mone Formation (exact locality and horizon are uncertain). They are referable to our *Nilssonia* sp. cf. *N. canadensis*, because his illustrated leaves as shown in his pl. 26, fig. 2 (basal part of a leaf) and fig. 3 (small-sized leaves) are indistinguishable from present corresponding leaves. Some species of taenioid (or belt-like) *Nilssonia* leaves such as *Nilssonia orientalis, N. canadensis*, *N. iollnstrupi* Heer, *N. taeniopteroides* Halle, *N. yukonensis* Hollick and *N. densinervis* (Fontaine) Berry has established. Bell (1956) already has been discussed of these species. In addition, Kimura and Tsujii(1983) discussed the systematic distinction among the taenioid (or belt-like) *Nilssonia* leaves hitherto described. I will discuss about this topic by additional specimens and information from the Tochikubo Formation.

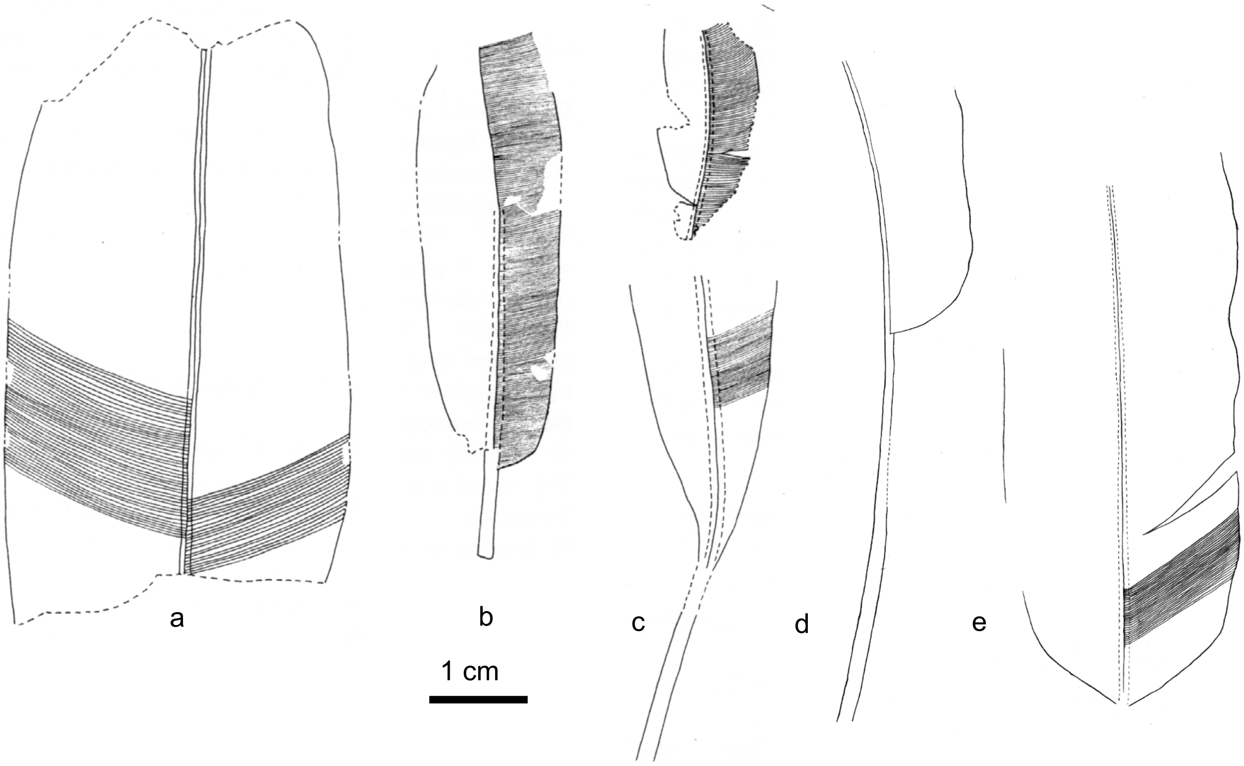


Figure 23. *Nilssonia* sp. cf. *N. canadensis* **a** (NSM PP-8300). **b** (NSM PP-8299). **c** (NSM PP-8303). **d** (SDS'05-105). **e** (SDS'05-563) a-c after Kimura and Ohana (1988b), d,e, after Ohana and Takimoto (2008).

Nilssonisa sp. cf. ***N. densinervis*** (Fontaine) Berry

Plate XV, 3, 4; Figure 24, 1

Material: NSM PP-8304 (Shidasawa), 8305, 8306 (Bunasaka), 8307-8310 (Aratozawa) and 19 other specimens.

Locality: Aratozawa and Shidasawa, Haramachi Ward, Minamisoma City, Fukushima Prefecture. Bunasaka Kashima Ward, Minamisoma City, Fukushima Prefecture.

Strata: Tochikubo Formation (Oxfordian), Somanakamura Group.

Description

Detached broken leaves, which are petiolate and variable in size and form were obtained. The lamina covers entirely the upper surface of thick rachis and is elongate-obovate in outline, typically dissected rather regularly into segments of varying width by the sinuses reaching the rachis except occasional leaves of which the laminae are irregularly dissected by shallow or deep sinuses. The segments are rectangular, irregularly quadrilateral or sub rhombic in outline and their upper margin is mostly straight, but their lower margin is convex forming a broad angle towards the outer margin, which is sometimes truncated. The veins are simple, straight and perpendicular to the rachis, but the lower ones in each segment bend upwards near the outer margin of segment. The vein density is also variable according to the leaf, typically 50-60 per cm; generally coarser in large leaf and denser in small leaf. The largest leaf is more than 10 cm long, nearly parallel-sided for the most part, and up to 4 cm wide. Its lamina is irregularly segmented by deep or shallow sinuses. Its rachis is up to 3.5 mm wide and its veins are invisible. (Original description in Kimura and Ohana, 1988b)

Remarks

Nilssonia densinervis was first described by Fontaine (1889) from the Lower Cretaceous Potomac Group as *Platypteridium densinerve* and *P. rogerisianum*. Most Fontaine's original leaves including those of his *Platypteridium rogerisianum* are similar and most close in leaf-form and mode of segmentation of lam-

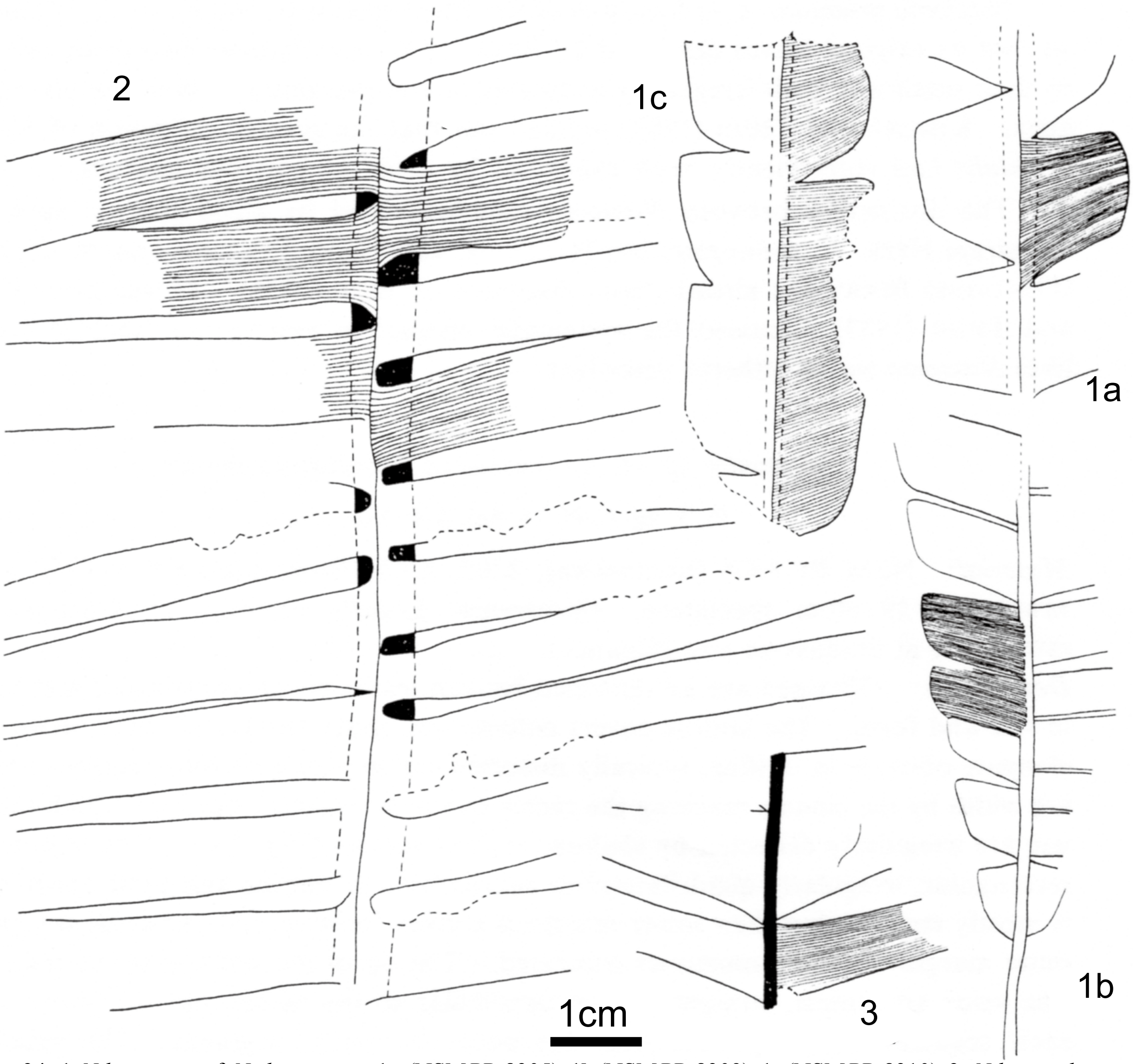


Figure 24. 1. *Nilssonia* sp. cf. *N. densinervis*. **1a** (NSM PP-8305). **1b** (NSM PP-8309). **1c** (NSM PP-8310). **2.** *Nilssonia longipinnata* (NSM PP- 8311). **3.** *Nilssonia oblique-trancata* (NSM PP-8327). after Kimura and Ohana (1988b).

ina to our leaves, but they are markedly large-sized [70 cm long and 15-18 cm wide, according to Berry (1911)]. As no such large-sized leaf has been found from the Tochikubo and Tomizawa Formations, Kimura and Ohana (1988b) regarded the leaves specifically as *Nilssonia* sp. cf. *N. densinervis*. Oishi (1940) and Kimura and Kansha (1978) described similarly sized leaf-fragments from the Lower Cretaceous Yuasa Formation in the Outer Zone of Southwest Japan as *Nilssonia densinerve* and *N. densinervis* respectively. Medium-sized leaves were also described by Oishi (1940) and Kimura and Ohana (1987b) from the Middle Jurassic Utano Formation as *Nilssonia densinerve* and *N.* sp. cf. *N. densinervis* respectively. One of the specimens resembles closely in leaf-form and mode of segmentation of lamina a leaf illustrated by Krassilov (1967) from the Lower Createceous of Southern Primorye as *Nilssonia densinervis*. Kimura and Ohana (1988b) made further discussion about this species.

Nilssonia longipinnata Kimura et Ohana

Plate XV, 5; Figure 24, 2

Material: Holotype; NSM PP-8311 (Bunasaka). Paratypes; NSM PP-8312 (Bunasaka), 8313, 8314 (Aratozawa). *Examined specimens*; NSM PP-8315-8318 and 21 other specimens.

Locality: Aratozawa, Haramachi Ward, Minamisoma City, Fukushima Prefecture. Bunasaka Kashima Ward, Minamisoma City, Fukushima Prefecture.

Strata: Tochikubo Formation (Oxfordian), Somanakamura Group.

Description

Leaf large, more than 23 cm long and more than 1 2 cm wide. (Whole leaf unknown.) Rachis thick, 0.5 mm wide at middle, 0.75 cm wide at the basal part of leaf and 0.2 cm wide at the distal part of leaf, giving alternately off the pinnae at nearly right angle. Pinnae closely set, elongate-rectangular in form, typically 1 cm wide and more than 9 cm long, entirely covering the upper surface of rachis, both acroscopic and basiscopic bases expanded, and adjacent basal laminae often contiguous each other laterally. Veins simple, parallel, typically 21 (about 20 per cm) in number in each pinna. (Original description in Kimura and Ohana, 1988a)

Remarks

Many large-sized specimens were obtained, but none of them was complete. However, the leaf must have been very large. The present leaf is characterized by the parallel-sided and elongate pinnae nearly perpendicularly to the rachis. Judging from the isolated pinna fragments, the present pinnae are supposed to have been 20 cm long, but pinna apices are all missing. The present leaves are comparable with those of the following *Nilssonia* species: *Nilssonia syllis* Harris from Yorkshire (Harris, 1964) is distinguished by its pinnae, typically not exceeding 5 cm long and gradually tapering distally. *Nilssonia pterophylloides* Nathorst (Nathorst, 1879) is distinguished by its obliquely set and widely spaced pinnae with small number of veins (up to 15 in number in each pinna). Under the circumstances, Kimura and Ohana (1988b) propose *Nilssonia longipinnata* sp. nov. to accommodate the leaves. *Nilssonia macrophylla* and *N. polymorpha* var. major originally described by Jacob and Shukla (1955) are most close to present species. But *Nilssonia macrophylla* is distinguished by its pinnae with densely crowded veins (40 per em) and *N. polymorpha* var. major by its much broader pinnae, sometimes twice as broad as present pinnae. In the backside view, the leaves would be taken to be those of *Pterophyllum*.

Nilssonia oblique-truncata Kimura et Ohana

Plate XVI, 1, 3; Figure 24,3 and 25

Material: Holotype; NSM PP-8319 (Aratozawa). Paratypes; NSM PP-8320, 8321 (ditto). *Examined specimens*; NSM PP-8322-8331 (ditto).

Locality: Aratozawa, Haramachi Ward, Minamisoma City, Fukushima Prefecture.

Strata: Tochikubo Formation (Oxfordian), Somanakamura Group.

Description

Leaf medium-sized, more than 13 cm wide. (Whole leaf unknown.) Rachis thick below, 3.5 mm wide but thinner above, sending off alternately long and narrow pinnae at an angle of 70 degrees, but angle reduced apically; laminae completely covering the upper surface of rachis. Lower pinnae more than 8 cm long and 0.7 cm wide, nearly parallel-sided for the most part, expanded at base, decurrent and obliquely truncated at apex; acroscopic apical margin sometimes cuspidately projected. Apical pinnae suddenly becoming shorter and narrower. Venis simple, parallel and ending at the

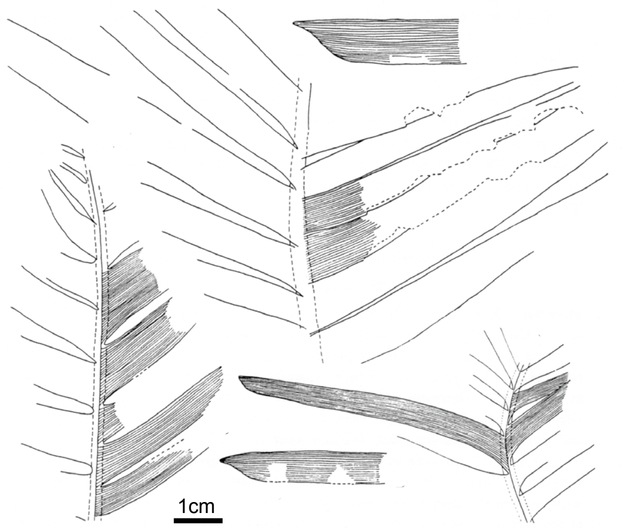


Figure 25. *Nilssonia oblique-trancata* **a** (NSM PP-8319, holotype). **b** (NSM PP-8320, paratype). **c** (NSM PP-8321) **d, e** (NSM PP-8321, paratype) after Kimura and Ohana (1988b)

truncated margin; 8 in number in a small-sized pinna and 18 in number in a large-sized pinna. (Original description in Kimura and Ohana, 1988a)

Discussion and comparison

The leaves are characterized by their long and narrow pinnae with obliquely truncated apex. Such an external feature has not been recorded except for a pinna fragment illustrated by Harris (1964) in *Pseudoctenis* sp. A. Therefore; Kimura and Ohana (1988b) proposed *Nilssonia oblique-truncata* sp. nov. to accommodate the leaves. *Nilssonia obique-truncata* resembles in external leaf-form *N. mediana* (Leckenby et Bean) Fox-Strangways, but is distinguished by its pinnae with obliquely truncated apex, instead of the latter pinnae with bluntly pointed or rounded apex (Seward, 1911, text-fig. 1~C). *Nilssonia oblique-truncata* is distinguished from *N. longipinnata* described in Kimura and Ohana (1988b) by its obliquely inserted pinnae, instead of the latter pinnae, which are unexceptionally, inserted perpendicularly to the rachis.

Nilssonia ex gr. ***schaumburgensis*** (Dunker) Nathorst

Plate XVI, 2 and XVII; Figure 26 and 30,1

Material: NSM PP-8332, 8333, 8335-8337 (Bunasaka), 8334, 8338-8345 (Aratozawa) and 175 other specimens.

Locality: Aratozawa and Shidazawa, Haramachi Ward, Minamisoma City, Fukushima Prefecture. Bunasaka, Koyamada and Kitanoirisawa Kashima Ward, Minamisoma City, Fukushima Prefecture.

Strata: Tochikubo Formation (Oxfordian), Somanakamura Group.

Description

The leaves are variable in external form, size and vein-density, but I think they belong to the same fossil population and thus belong to one and the same species because of their occurrence. The leaf is long and narrow; the largest ones are more than 18.6 cm and 17 cm and up to 1.8 cm and 1.3 cm wide respectively. The lamina is entire or irregularly dissected by the sinuses reaching or not reaching to the rachis.

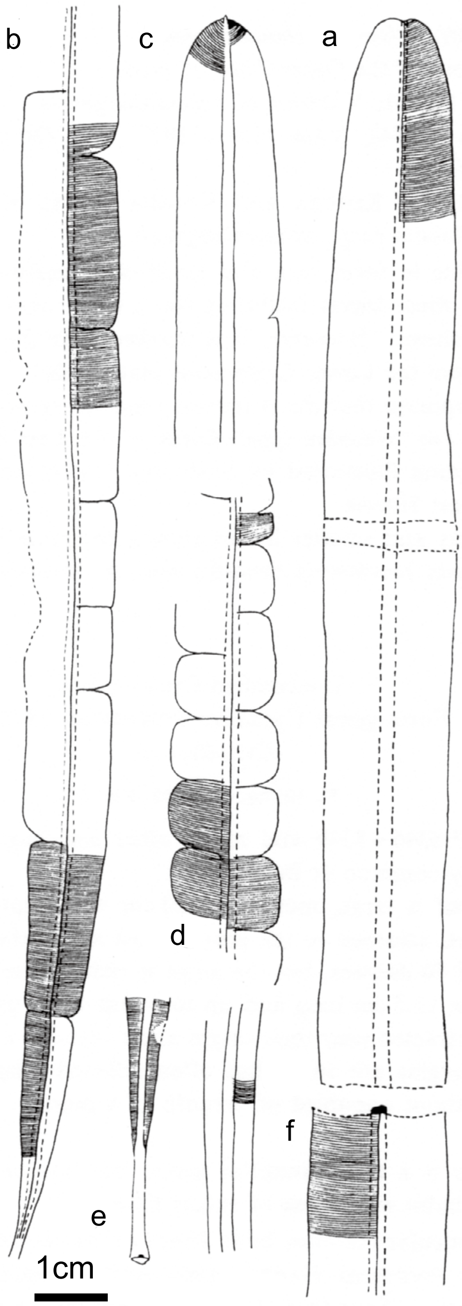


Figure 26. *Nilssonia* ex gr. *schaumbergensis* **a** (NSM PP-8340). **b** (NSM PP-8342). **c** (NSM PP-8344). **d** (NSM PP-8338). **e** (NSM PP-8334). **f** (NSM PP- 8335). after Kimura and Ohana (1988b)

Plate XVI, 2 shows a distal half of leaf in which the lamina is nearly parallel-sided for the most part, abruptly narrowing towards the broadly rounded and shallowly notched apex; margins are entire.

Plate XVII, 1 shows a proximal half of leaf in which the lamina is irregularly and broadly segmented; the incisions are mostly V-shaped and the corners of each segment are mostly rounded. The veins are simple and perpendicular to the rachis and the density is 30~40 per cm in the leaf. Plate XVII, 3 shows a proximal half of leaf in which the lamina is narrowing towards the cuneate base. (Original description in Kimura and Ohana, 1988a)

Remarks

Common features of the variously formed and sized leaves are as follows: l) Surface of lamina is flat or convex upwards. 2) Their laminae unexceptionally cover entirely the upper surface of rachis except for the basal part of a leaf. 3) Veins are prominent, arising perpendicularly from the rachis except for the apical portion of a leaf where the angle is slightly reduced. 4) Concentration of veins is 30-60 per cm. 5) All leaves are represented by their adaxial surface exposed and in these, the rachis is seen only when the substance of the lamina is broken away, but in all leaves its position is indicated by a depression of the lamina. The depression retains its width to the distal part of the leaf. Similar leaves have been described as follows:

Lower Cretaceous of North Germany:
 Dunker (1846); *Pterophyllum schaumburgense*,
 Schenk (1871); *Anomozamites schaumburgensis*

Lower Cretaceous of England:
 Seward (1895) and Watson (1969); *Nilssonia scha umburgensis*

Lower Cretaceous of North America;
 Fontaine (in Ward, 1905) and Bell (1956); *Nillsonia schaumburgensis*

Lower Cretaceous of Southern Primorye:
 Krassilov (1967); *Nilssonia schaumburgensis*

Lower Cretaceous of South Korea:
 Tateiwa (1929) and Oishi (1940); *Nilssonia schaum burgensis* and *N. schaumburgensis* var. *parvula*

Upper Jurassic of Northeast Japan (possibly from the Tochikubo Formation):
 Oishi (1940); *Nilssonia schaumburgensis*

Lower Cretaceous of the Outer Zone of Japan:
 Nathorst (1890); *Nilssonia* cf. *schaumburgensis*
 Yokoyama (1894), Yabe(1913, 1927) and Oishi (1940); *Nilssonia schaumburgensis*,
 Kimura (1976), Kimura and Kansha (1978), Kimura and Matsukawa (1979) ; *Nilssonia* ex gr. *schaumbur gensis*.

They are variable in form, size and mode of segmenation, but it is difficult to separate specifically these leaves including the present ones on the basis of their external morphology alone. However, it is marked that the present leaves are larger in size than those from the Lower Cretaceous plant-beds. I am of the opinion that the *Nilssonia schaumburgensis*-type leaves are peculiar to the Ryoseki-type (or 'Wealden-type') floras of the Late Jurassic-Early Cretaceous time.

Some important specimens of *Nilssonia schaumburgensis* with long and short shoots were collected by Muneo Taira who one of the local collector. Takimoto et al. (1997) established new species of *Nilssoniocladus* Kimura and Sekido on the basis of these specimens.

Genus ***Nilssoniocladus*** Kimura and Sekido, 1975

Type species: *Nilssoniocladus nipponensis* (Yokoyama) Kimura and Sekido : Lower Cretaceous Oguchi Formation, ltoshiro Group, Tetori Supergroup in the Inner zone of Japan.

Generic diagnosis:Stem in ultimate parts slender, branched, consisting of long and short shoots, woody. Long shoot with long and smooth internodes, and bearing short shoots spirally. Short shoots covered with spirally placed rhomboidal leaf scars and at apex bearing a group of 'Nilssonia' leaves. All leaf scars essentially similar no scale leaf scars among them. Not possible to observe whether short shoots are in the axil of a leaf or of a scale leaf (Kimura and Sekido, 1975, p. 113).

Nilssoniocladus tairae Takimoto, Ohna et Kimura

Plate XVIII and XIX, 4; Figure 27

Material: Holotype: KHFM-210007. Paratype: KHFM-210006 (counterpart of the holotype). Other specimens: KHFM-210005, 210008, 210009, 210011, 210016.

Locality: Karamatsyrindo-minamishisen 3, Kashima Ward, Minamisoma City, Fukushima Prefecture.

Strata: Tochikubo Formation (Oxfordian), Somanakamura Group.

Specific diagnosis

Long shoot slender, 1.2 cm wide, giving off short shoots, each terminally with a rosette of seven large-sized leaves. Leaf lamina regularly and deeply cut, forming more than 35 pairs of pinnae. Pinnae rectangular with pointed apices. Petiole shorter with 5-6 pairs of small-sized oval or semicircular pinnae. Veins numerous, simple, parallel, and not convergent at pinna apex.

Description:

Long and short shoots are present. Preserved part of long shoot is 16 cm long and I .2 cm (partly 1 .4 cm) wide, with roughly striated surface; no other definite scars have been found on the surface. Preserved part of short shoot is 1.5 cm in diameter, and about 5 mm long (or high). Crushed rhomboidal petiole scars are rarely observed on the surface of the short shoots (Figure 27, b). Terminally, the short shoot gives off at least seven leaves, forming a leaf rosette. Estimated length of the internodes between successive short

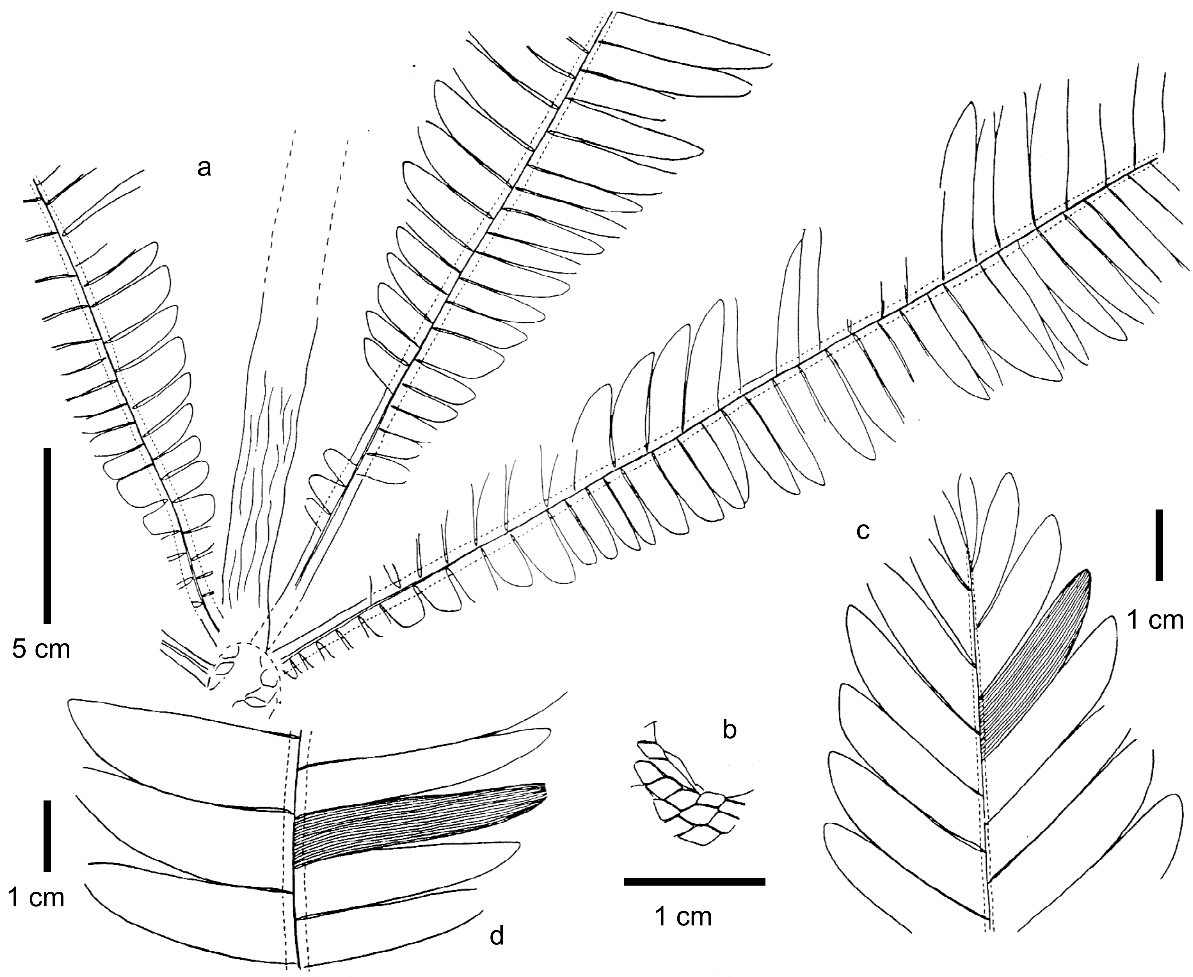


Figure 27. *Nilssoniocladus tairae.* **a** (KHFM-210006, paratype). **b** (KHFM-210016, short shoot). **c** (KHFM-210011). **d** (KHFM-210007, holotype) after Takimoto et al. (1997).

shoots is 18-20 cm. Details of mode of arrangement of short shoots on the long shoot are, however, uncertain. The leaves are large, oblanceolate, more than 30 cm long and up to 8 cm wide. The rachis is prominent, 3-4 mm wide, and has a short and thick petiole, which is less than 1 cm long and 4 mm wide; the base of the petiole is slightly expanded and in organic connection with the top of a short shoot. Leaf lamina is regularly and deeply cut, forming more than 35 pairs of pinnae. Pinnae are typically rectangular; acroscopic margin is nearly straight, and basiscopic margin is rounded apically. The pinnae of the holotype are 41 mm long and 9 mm wide, rarely narrower; those of the proximal 5-6 pairs are small and oval or semicircular (Figure 27, a). Veins are prominent, numerous, simple, parallel, and not convergent at pinna apex; 18 in number in each pinna (22-23 per cm in density). Leaf cuticle is not preserved, and reproductive organs are not observed.

Remarks

This new locality of the Tochikubo Formation has yielded a' new type of *Nilssoniocladus* leaves as described above. Some leaves are in organic connection to the short shoots of *Nilssoniocladus*, and form a leaf rosette. The leaves also occur as fragments of leaf rosettes in which short shoots are missing. Most parts occur as detached leaves, forming '*Nilssonia*' leaf-mats on the bedding plane. Therefore, the leaves of this species appear to be deciduous. Many leaves have expanded petiole bases. In our new collection, no detached scar of a short shoot has been found on the surface of a long shoot. I suggest that the short shoots of *Nilssoniocladus tairae* probably belong to a younger development stage, possibly when the plants were two or three years old, because they are shorter in length and not so prominently elongated on the long shoot. The surface of the long shoot and of the depressed short shoot, and the proximal portions of rachis and petiole are covered with a faded brownish substance. It is probable that these brown stains are due to some resinous substance oozing out from the woody part of the plant. The abaxial side of the leaves may resemble leaves of bennettitalean *Pterophyllum* and *Ptilophyllum*, in some aspects because the present rachises are markedly exposed in abaxial view. However, laminae of the present leaves completely cover the rachises in adaxial view. This is a characteristic feature of the *Nilssoniocladus* and '*Nilssonia* ' leaves. So far as we know, the leaves of *Nilssoniocladus tairae* are unique in size, shorter petiole and small-sized proximal pinnae. (Takimoto et al., 1997)

Nilssoniocladus japonicus Takimoto, Ohna et Kimura

Plate XIX, 1-3; Figure 28

Material; Holotype; KHFM-210003, Paratype; KHFM-210002, KHFM-210001, 210004, 210018, 210019.

Locality: Karamatsyrindo-minamishisen 3, Kashima Ward, Minamisoma City, Fukushima Prefecture.*Locus typicus*: Same as *Nilssoniocladus tairae*

Strata: Tochikubo Formation (Oxfordian), Somanakamura Group.

Specific diagnosis: Each short shoot giving off at least seven leaves. Leaves closely helical at apex of a short shoot, forming a leaf rosette. Leaves long and narrow, nearly parallel-sided, variable in form and size.

Description

Preserved long shoot is 8 cm long and 7 mm wide with poorly preserved ornamentation on its surface. Short shoot is 1 cm in diameter, and low cylinder-like. The internode between successive short shoots is estimated to be 3.5 cm long. Leaves are long and narrow, more than 14 cm long and up to I .3 cm wide, and have rather stout petiole which is 5.5 cm long and 4 mm wide. Seven helically arranged leaves are borne at the top of the short shoot, and form a leaf rosette. Leaf laminae are nearly parallel-sided, completely covering upper surface of prominent rachis. Leaves are variable in form. Some leaves are with entire or irregularly undulated or shallowly dissected margins, some leaves are rather deeply dissected into rectangular segments

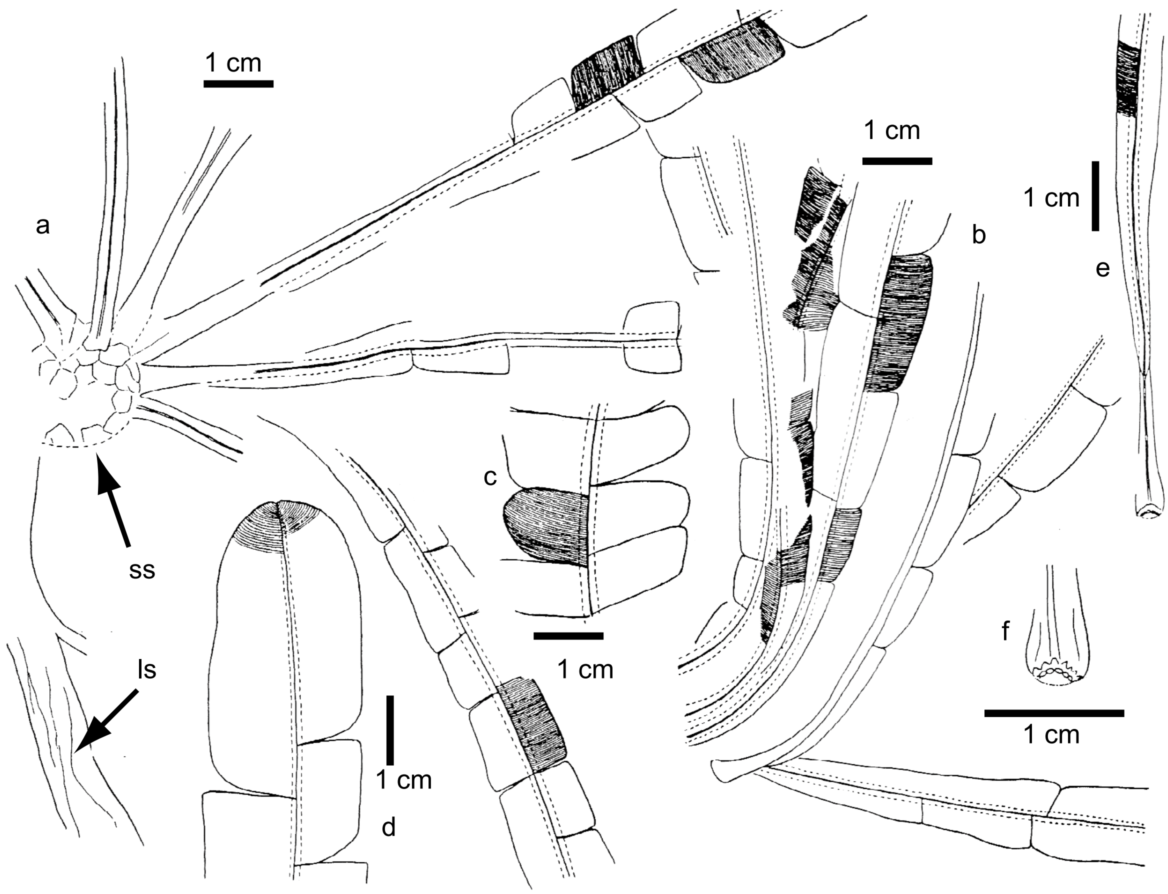


Fig. 28. *Nilssoniocladus japonicus.* **a** (KHFM-210002, paratype). **b** (KHFM-210018, detached leaves). **c** (KHFM-210001). **d** (KHFM-210001, holotype). **e** (KHFM-210019). **f** (KHFM-210019). afterTakimoto et al., (1997).

with truncated distal margins, and some leaves are dissected into semicircular segments (pinnae) (e.g. Kimura, 1976; Kimura and Ohana, 1988b). These leaf-types are specifically inseparable, and may be included in a wide range of continuous intraspecific variation. The largest lamina is more than 17.5 cm long and 2.1 cm wide. Apex is broadly rounded or sometimes shallowly emarginate. The petiole base is expanded laterally. In some oases, several vascular bundle scars (?) are seen in a semicircular row (Figure 28, f). Veins are densely crowded, simple, parallel and typically 44 per cm. Cuticle is not preserved and the reproductive organs are not observed.

Remarks

The leaves of *Nilssoniocladus japoonicus* were found detached and piled up together on the same bedding plane, indicating that they were deciduous. These detached leaves are similar in form to those originally described by Dunker (1846) as *Pterophyllum schaumburgense* from the Wealden beds of North Germany, and later transferred to *Nilssonia* by Nathorst (1890) based on specimens collected from Lower Cretaceous sites in the Outer Zone of Japan. However, it is still uncertain whether the Japanese leaves are really conspecific with the German leaves or not, because neither preserve cuticles. We provisionally described tbe detached Japanese leaves as '*Nilssonia* ' ex g r. *schaumburgensis* (Dunker) Nathorst or '*Nilssonia* ' sp. cf. '*N*' schaumburgensis (Dunker) Nathorst. Generally, Late Jurassic '*Nilssonia* ' *schaumburgensis*-like leaves in Japan are nearly twice as large as those of Early Cretaceous leaves in Japan. I proposed *Nilssoniocla-*

dus japonicus sp. nov. for the Jurassic specimens having larger leaves. The surface of long and short shoots is also covered with a faded brownish substance of the same probable origin as suggested above.

Comparison and discussion

As shown in the original line drawing, the type species *Nilssoniocladus nipponensis* has a slender long shoot with a smooth surface (Kimura and Sekido, 1975, text-fig. 1). No surface ornamentation, such as longitudinal wrinkles, short shoot scars and growth increment boundary like those reported ' for *Nilssonioc ldus alaskensis* Spicer and Herman (Spicer and Herman, 1996), has been observed. In *Nilssoniocladus chukotensis* Spicer and Herman, short shoots were shed together with the leaf rosettes (Spicer and Herman, 1996). Such a shedding of short shoots has so far not been recognized in the Japanese species. There are many plant sites in the Tochikubo Formation, but the occurrence of *Nilssoniocladus tairae* and its detached leaves appears to be restricted to the new locally. Therefore, *Nilssoniocladus tairae* is considered to be a local or endemic species in the Tochikubo Formation. Matsuo (1976) illustrated mature and developed short shoots terminally with a cluster of three leaves and two scar-like imprints on a slender long shoot from the Lower Cretaceous Oguchi Formation in the Inner Zone of Japan. In his paper (written in Japanese), he regarded these leaves as *Nilssonia nipponensis*, igncring the established genus *Nilssoaiocladus* (Kimura and Sekido, 1975). Although Matsuo's line-drawing is simplified, the specimen might belong to *Nilssoniocladus*. The leaves have a characteristic toothed margin and are in our view probably assignable to *Nilssoniocladus lobatidentatus* (Vassilevskaja) known from the Lower Cretaceous of the Lena Basin (e.g. Vassilevskaja et al., 1972). Detached leaves with toothed margin also occur from the Lower Cretaceous of the Tetori Basin in the Inner zone of Japan (Kimura and Sekido, 1976a, b). Krassilov 1975, fig. 18) illustrated a *Nilssoniocladus*-like shoot with a cluster of leaves, but there are no morphological details. *Nilssonia schaumburgensis* (Dunker) described by Watson (1969) from the English Wealden beds includes leaf fragments with preserved cuticle. Its laminae are irregularly and shallowly dissected, and have an emarginate apex. Some leaves are regularly dissected, but the sinuses do not reach to the rachis and the venation is not crowded. Although such English leaves superficially resemble the Japanese leaves of '*Nilssonia*' ex gr. *schaumburgensis* or '*N*' sp. cf. '*N*' *schaumbufgensis*, it is uncertain whether these English leaves are conspecific with the Japanese leaves described here. The *Nilssoniocladus* plants are considered to be woody climbers, because their slender long shoots bearing the load of large-sized leaf rosettes could not have kept the plants upright. it is likely that the number of *Nilssoniocladus* species will increase in future. Because I know a number of the tufts of '*Nilssonia*' leaves hitherto described, all of which seem to converge toward a common point. An attached table shows a list of define *Nilssoniocladus* species hitherto known. (Takimoto et al., 1997)

Unclassified Cycadopsida

Genus ***Encephalartites*** Vachrameev 1962

Type species.- ***Encephalartites leipzigii*** Vachrameev, 1962

Encephalartites nipponensis Takimoto et Ohana

Plate XX, 1-3

Material: MM008487 (Holotype), MM008488-008496, INM-4-013792, 013793, 013794, 013795 (Ibaraki Nature Museum)

Locality: Shidazawaike, Haramachi Ward, Minamisoma City, Fukushima Prefecture.

Strata: Tochikubo Formation (Oxfordian), Somanakamura Group.

Diagnosis:

Leaves simply pinnate, rachis robust, leaflets narrow and linear, basally symmetrical and contracted, taper-

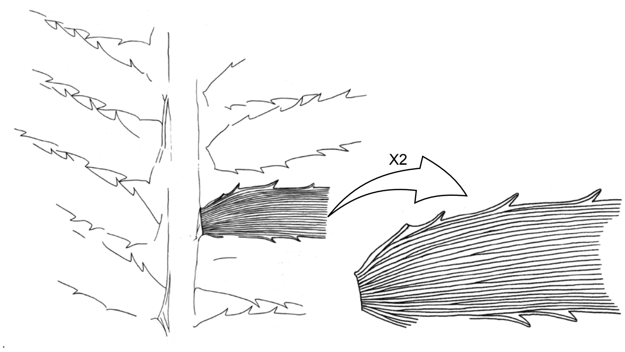


Figure 29. *Encephalartites nipponensis*. (MM008487) after Takimoto and Ohana, (2016).

ing towards the apex, attached alternately or suboppositely, at wide angle to the upper surface of the rachis; margin toothed on both sides. Venation, parallel; some veins them forking dichotomously; veins at the lamina margin fork dichotomously with one of the branches extending into a spine.

Description

Leaves are simply pinnate; the longest preserved portion is 22 cm long and 21 cm wide. Fully-grown leaves are estimated at least 50 cm long and over 25 cm wide. The base and apex of leaves are not preserved in the available specimens. The rachis is stout, 0.9 cm wide at the middle part (Plate XX, 1), decreasing towards 0.2 cm wide near the top of the leaf. Leaflets are linear to narrow lanceolate. The largest leaflet is more than 12 cm long and 1.5 cm wide (Plate XX, 2). Leaflets are slightly decreasing in size at the apical portion. The leaflet margin is characterized by eight to ten irregularly placed spinous teeth (Figure 29). The leaflets are attached alternately to suboppositely and have contracted base (Plate XX, 1,2); they arise from the upper surface of the rachis at angles of 70-80 degrees, and the angle becomes progressively more acute towards apex. The veins are parallel and often dichotomizing; at the marginal lamina bifurcate with one of the branches extending straight into each tooth (Figure 29). Twenty to 26 veins occur in the middle part of leaflet (Figure 29). Unfortunately, cuticle could not be obtained from the specimens.

Discussion and Comparisons

Several types of one-pinnate cycadophyte foliage with parallel- veined leaflets and serrate or toothed margin are known from the Mesozoic including *Encephalartites*, *Encephalartopsis*, *Neozamites*, *Baikalophyllum*, *Rehezamites*, *Moltena*, and *Jirusia*. Cycads, which have similar external morphological characters, are still in existence today; these include for example different *Encephalartos* species.

Comparison with extinct cycadophyte foliage

Fontaine (1889) established the cycadalean genus *Encephalartopsis* from the Lower Cretaceous. Present specimens are similar in the shape of leaflet to *Encephalartopsis*. However, the venation of our specimens is definitely different from that of *Encephalartopsis*. The veins of *Encephalartopsis* are occasionally anastomosing by branches sent off abruptly from one nerve to another, which is not seen in our specimens.

Neozamites, established by Vachrameev(1962), is characterized by pinnate leaves with markedly toothed leaflet margins and with bennettitalean cuticle. *Neozamites* species were recorded in China, Eastern Siberia and Japan. Sun et al. (1993) described two species of this genus from Japan. The leaflets of *Neozamites* are attached to the upper part of the axis by a small area of leaflet base, and have an elongate rectangular to roundish outline. The shape and attachment of the leaflets of *Neozamites* is different from those of present specimens. Veins of *Neozamites* are sent off radially from the point of attachment of the leaflets, whereas our specimens display a parallel venation, where veins emerge from several occasions at the attachment point. *Neozamites* has been confidently placed in the Bennettitales based on the occurrence of brachyparacytic stomata.

Du Toit (1927) established the cycadalean genus *Moltenia* from Triassic strata in South Africa. This genus is characterized by variously toothed pinnae. Anderson and Anderson (1989) described four species of *Moltenia* including the type species from the Gondowana Triassic. The simple marginal teeth of the leaflets of *Moltenia dentata* and *M. gracilidentata* are similar to the margin of our specimens, however, the blunted and irregularly serrate tip and the small size of the leaf are the major differences to our specimens. The leaflets of *M. paucidentata* are same size to our specimens; however, the round shaped tip of the leaflet is different from our specimens. The irregularly lobed leaflet of *M. feistmantelii* is very different from our specimens, too. The decurrently leaflet base of *Moltenia* leaves is generally different from the contracted base of *Encephalartites*.

Kvaček (1995) compared *Encephalartites* with the cycadalean genus *Jirusia* from the Bohemian Cenomanian, which also has a serrate or toothed leaflet margin. Morphological characters of *Encephalartites* recall *Jirusia*, however, the former differs in the shape of the leaflets and the more frequently dichotomizing veins.

Horiuchi and Kimura (1987) established the genus *Dioonopsis* for cycadean leaves from the Palaeogene Noda Group of Northeast Japan. Morphological characters of the leaflet of *Dioonopsis* are similar to the present specimens. However, there is a definite difference between them. The leaflet of *Dioonopsis* is attached to rachis with a remarkably wide base. Veins of *Dioonopsis* are occasionally anastomosing. Erdei et al. (2012) described *D. praespinulosa* and *D macrophylla* from the Eocene of North America. They also have very broad leaflet bases and anastomosing veins.

Recently, Pott et al. (2012) revised two seed plants *Baikalophyllum lobatum* and *Rehezamites anisolobus* with cycadophyte foliage from the Early Cretaceous of Eastern Asia. Leaves of *Baikalophyllum lobatum* have simple lobate blades and each lobe has a median incision. Leaves of *Rehezamites anisolobus* have once-pinnate leaves; several lobes are present along the acroscopic margin of the leaflets. These external morphological features of the leaves are different from our specimens from both species.

Our specimens have several macromorphological features in common with *Encephalartites*. These are the symmetrical and contracted base of the leaflet, which is, moreover, attached to the edge portion of the upper surface of the rachis. The margin of leaflet is toothed with several spines. The venation in the middle portion of the leaflets is parallel, with a few of them bifurcate dichotomously; lateral nerves bifurcate dichotomously with one of the branches extending into the spine.

The closest related species is *Enceohalartites leipzigii* from Lower Cretaceous of Yakutia, the Lensky basin, Russia (Vachrameev, 1962). Its leaflets are 90-100 mm long and 7-8mm wide. Leaves of *E. nipponensis* specimens are considerably larger than *E. leipzigii* in all measurements. Leaflets of *E. leipzigi* are attached to the rachis at opposite position, whereas in *E. nipponensis*, they are predominantly attached alternatingly. Veins of *E. leipzigii* are 10-12 in number; our specimens are characterized by 20 to 26 veins in the middle part of the leaflet. These differences allow me to establish a new species, named *Encephalartites nipponensis.*

Comparison with extant cycads

Some of the morphological features in our specimens are similar to certain species of the extant genus *Encephalartos*. Especially, *Encephalartos munchii* is quite similar to the here presented specimens. The leaflets of *Encephalartos munchii* are lanceolate, moderately crowded and evenly spaced throughout, obliquely erect to form a shallow V, instead inserted to the rachis at about 70°. The spinous teeth are reduced in number and size from the base to near the apex of the leaflets; the venation is irregular and parallel (Jones, 1993). Some extant *Dioon* species also have similar morphological features in the leaflet, but in these species, the base of the leaflet is broad and decurrent (Jones, 1993). (Takimoto and Ohana, 2016)

Unclassified Cycadopsida

Form-genus ***Cycadites*** Sternberg, 1825

Cycadites sp.

Plate XX, 4; Figure 30, 2

Material: NSM PP-8346 - 8349 and many other leaf-fragments (Bunasaka).

Locality: Bunasaka, Kashima Ward, Minamisoma City, Fukushima Prefecture.

Strata: Tochikubo Formation (Oxfordian), Somanakamura Group.

Description

The leaf is large, more than 20 cm wide, but whole leaf is unknown. Pinnae are closely set, attached to the grooves just above the lateral margins of stout rachis at an angle of 70 degrees, but the angle is reduced towards the apex. Pinnae are linear, more than 11.5 cm long and up to 5 mm wide, parallel-sided for the most part, but slightly contracted near their origin and expanded at their base; pinna apices are all missing. Margins are entire but often reflexed longitudinally. Midnerve is distinct, occupying about one-third of breadth of a pinna. Reproductive organs are not known. (Original description in Kimura and Ohana, 1988b)

Remarks

Cycadites is a non-committal genus, but has been used for fossil leaves agreeing in external habit with those of extant Cycas. Based on the cuticular features, both *Pseudocycas* Nathorst, 1907 with syndetocheilic stomata and *Paracycas* Harris, 1964 with haplocheilic stomata have been picked out of *Cycadites*. Therefore, it is now impossible to determine the attribution of such fossil leaves resembling those of extant *Cycas* only on the basis of their external morphology. Among a good number of species hitherto described under the generic names of *Cycadites*, *Pseudocycas* and *Paracycas*, our leaf is externally quite close, especially in size, to those of *Pseudocycas insignis* originally described by Nathorst (1907) from the Cenomanian plant-bed of Greenland. Our leaf is characterized by its large-size, and is distinguished from those of other *Cycadites* species mentioned below:

*Cycadites blomqvist*i Antevs: Antevs, 1919; Liassic of Sweden: Its rachis is far thicker than ours.

C. saladini Zeiller: Zeiller, 1902-3; Norian of North Viet Nam : Its leaf is narrower, up to 10 cm wide.

viously of the cycadalean-type, and *Nilssonia pecten* described also by OISHI from the same formation on the basis of splendid leaves is, according to Krassilov (1967) synonymous with *Cycadites sulcatus*. In Japan, similar leaves have been described from the upper Liassic Negoya Formation (Kimura and Tsujii, 1983), Middle Jurassic Utano Formation (Kimura and Ohana, 1987b). But they are all represented by the small-sized leaves.

Coniferales

Conifers are rare in occurrence and only represented by three forms, *Elatocladus* sp. A, *Pagiophyllum* sp. and *Parasequoia* sp. cf. *P. cretacea*. What is worse, as they are all represented by sterile broken leafy-shoots, it is difficult to make their specific or even generic attribution.

Form-genus ***Elatocladus*** Halle, 1913

Elatocladus sp. A

Plate XXI, 1

Material: NSM PP-8350 (Bunasaka), 8351 (Aratozawa).

Locality: Bunasaka, Kashima Ward, Minamisoma City, Fukushima Prefecture. Aratozawa, Haramachi Ward, Minamisoma City, Fukushima Prefecture.

Strata: Tochikubo Formation (Oxfordian), Somanakamura Group.

Description and remarks

The leafy-shoots are referable to non-committal genus *Elatocladus* redefined by Harris (1979) as 'fossil conifer shoot bearing elongated, dorsiventrally flattened leaves with a single vein and leaves divergent from stem'. The leaves are elongate-elliptical in form, sessile, 0.8 cm long and up to 2 mm wide, with rounded apex and attached oppositely to the axis. They appear to be originally decussate in arrangement, then their leaf-bases bending and twisting to bring each lamina into the horizontal plane and at right angle to the axis. (Original description and remarks in Kimura and

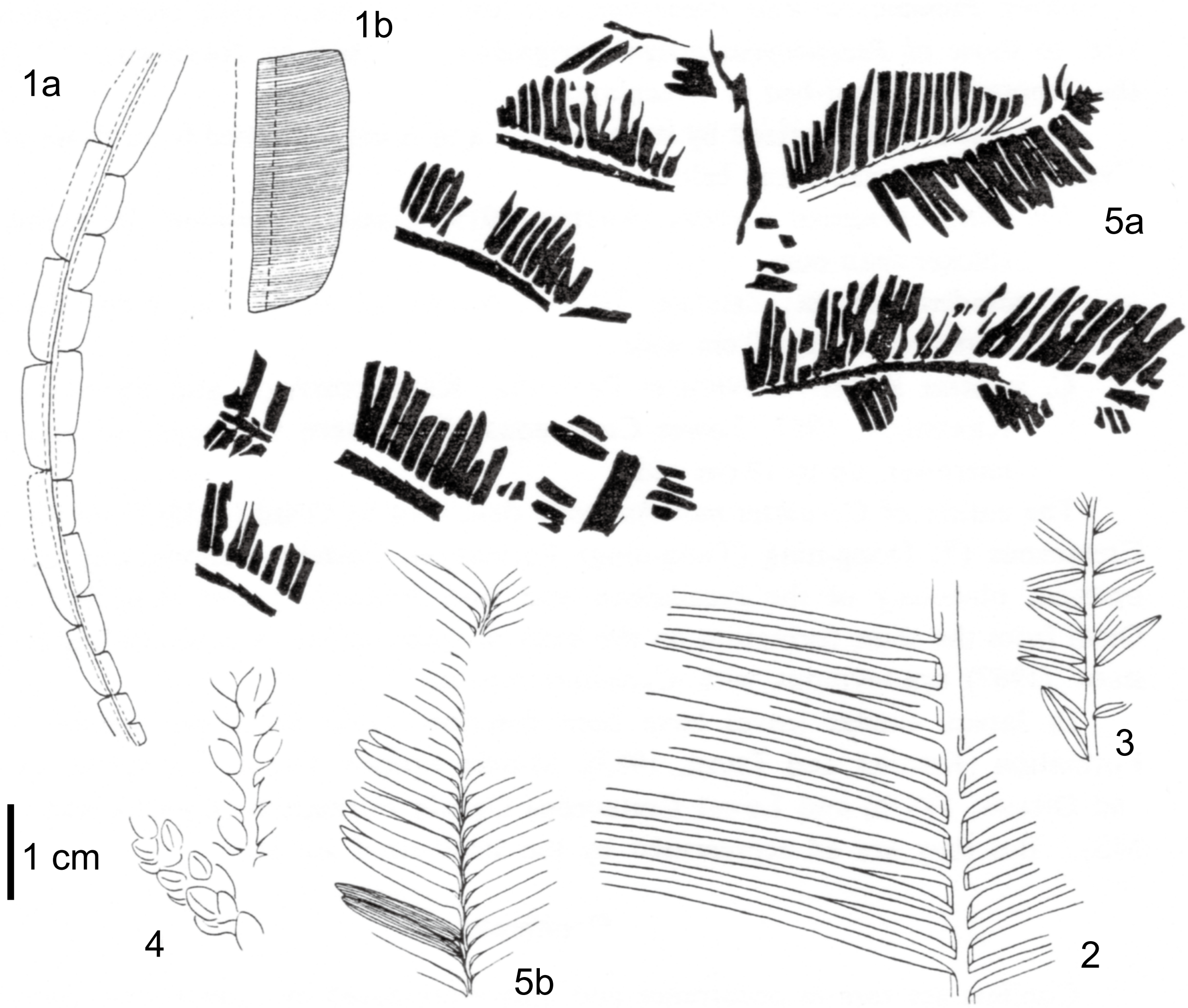


Figure 30. **1.** *NIlssonia* ex gr. *shaumbergensis*. **1a, 1b** (NSM PP-8343). **2.** *Cycadites* sp. (NSM PP-8347). **3**. *Elatocladus* sp. A (NSM PP-8351). **4.** *Pagiophyllum* sp. (NSM PP-8385). **5.** *Parasequoia* sp. cf. *P. crenata*. **5a** (NSM PP-8354). **5b** (NSM PP-8352). after Kimura and Ohana (1988b).

Ohana, 1988b)

Comparison

Elatocladus sp. B and *E*. sp. C described from Oginohama Formation and Kogoshio Formation respectively. (Kimura and Ohana, 1989b, 1991b)

Form-genus ***Pagiophyllum*** Heer, 1881

Pagiophyllum sp.

Plate XXI, 2-6; Figure 30,4

Elatocladus obtuslfolia Oishi : Oishi, 1 940, pl. 41, figs. I, I a (Kami-Mano-mura ;~possibly from the Tochikubo Formation).

*Materia*l: NSM PP-8373, 8374 (Umenokizawa), 8375-8386 (Fukounonakayama).

Locality: Umenokizawa Soma City, Fukushima Prefecture. Fukounonakayama, Haramachi Ward, Minamisoma City, Fukushima Prefecture.

Strata: Tochikubo Formation (Oxfordian), Somanakamura Group.

Description

Obtained are all small fragments of coniferous leafy-shoots. The branch-stem preserved is 6 mm wide; send off slender and delicate ultimate leafy-branches at a wide angle. The ultimate branches are not flattened, more than 3 cm long with slender axis. The leaves are arranged helically, widest at base or just above it, envelop the axis closely; probably thick and succulent; not adherent but free, directed forwards, diverging, markedly falcate at the distal portion, oval in abaxial view, with obtusely pointed or rounded apex, markedly convex and keeled abaxially and flat or concave adaxially, then triangular in form transversely; leaf-bases normally concealed by leaves below; typically 1.5 mm long and up to 1 mm wide. Reproductive organs are not known. (Original description in Kimura and Ohana, 1988b)

Remarks

The detached ultimate leafy-branches of delicate habit are locally common at the Fukounonakayama locality, but none of them is complete. The present coniferous leafy-branches are characterized by very slender axis covered with helically arranged, closely set, thick, oval-shaped, free, markedly keeled and falcate leaves. On the fracture of matrix, these leaves are usually preserved only leaving their keels and missing the convex part of leaves (Plate XXI, 5). Oishi (1940) instituted *Elatocladus obtusifblia* on the basis of sterile coniferous leafy-branches obtained from Kami-Mano-mura locality (possibly from the Tochikubo Formation). The diagnosis given by Oishi is 'shoot with pinnate (?) branching; habit slender; branchlets narrower; leaves deltoid, with an obtuse apex, and a dorsal keel decurrent at the base, crowded, sometimes recurved, arranged in spiral, and at a wide angle to the axis, the lamina being free except the base'. Kimura and Ohana, 1988b recognized that Oishi's leafy-branches are the same as those of ours. Possibly he did not observe the real leafy-branches, but observed those fructured by various planes. Oishi (1940) compared his leafy-branches with those of *Muscites sternbergianus* originally described by Dunker (1846) from the Wealden of Germany. But Dunker's leafy-branches (in his pl. 7, fig. 10) are quite different in leaf-form from present specimens. The coniferous leafy-branches described by Krassilov (1967) as *Elatocladus obtuslfolia* from the Lower Cretaceous of Southern Primorye are referable to the present *Pagiophyllum* sp. The general feature of our leafy-branches may fit in the emended diagnosis of Pagiophyllum given by Hsrris (1979). Our leaves resemble those of *Pagiophyllum maculosum* Kendall known from Yorkshire (Harris, 1979), but differ in their far smaller size. The leaf-cushion of the present *Pagiophyllum* sp. differs in habit from that of *Brachyphyllum*.

Form-genus ***Parasequoia*** Krassilov, 1967

Parasequoia sp. cf. **P. *cretacea*** Krassilov

Plate XXI, 7-9; Figure 30, 5

Material: NSM PP-8352-8372 (Aratozawa), KHFM-210035 (Tatenosawa) and 29 other specimens.

Locality: Bunasaka and Tatenosawa, Kashima Ward, Minamisoma City, Fukushima Prefecture. Aratozawa, and Shidazaawaike, Haramachi Ward, Minamisoma City, Fukushima Prefecture.

Strata: Tochikubo Formation (Oxfordian), Somanakamura Group.

Description

Leafy-shoots are preserved in fiat. Main axis preserved is thick, 2.5mm wide, sends off oppositely ultimate leafy-branches at a wide angle. Ultimate leafy-branch is more than 4.7 cm long and 2 cm wide, nearly parallel-sided for the most part, and with thick axis; some are terminated by a cone-like organ. In the leafy – shoots from Tatenosawa, the small leaves covering the axis are clearly shown (Plate XXI, 8). Leaves are shortly petioled, numerous, possibly decussately arranged but decurrent petioles bend and twist to bring each lamina into the horizontal plane and at a wide or a right angle to the axis. The leaf-1amina is linear, long and narrow, nearly parallel-sided for the most part, typically 1.5 cm long and 2 mm wide, obtusely pointed at apex and rounded at base. Veins are simple, parallel, 5 in number in each leaf, and end at the distal margin, not converge at apex.

Remarks

Our leaf is characterized by its parallel veins. Externally our leafy-branches resemble closely those of *Parasequoia cretacea* originally described by Krassilov

(1967) from the Lower Cretaceous of Southern Primorye. However, I regard our leafy-branches as *Parasequoia* sp. cf. *P. cretacea*, because our leafy-branches are only represented by impressions and our leaves are more longer than Krassilov's leaves. The details of the terminated cone-1ike organs are still uncertain.

This conifer is known from the Upper Jurassic plant-site of the Tochikubo, Oginohama and Mone Formations distributed along the Pacific side, northeast Japan.

Unclassified plants

Form genus ***Taeniatus*** Takimoto, Ohana and Kimura

Type species:***Taeniatus elongatus***

Diagnosis:Leaves large, fasciculate, attached to a short shoot-like organ. Leaf long and narrow; margins parallel-sided, through out with a strong midvein. Leaves not branched.

Discussion and comparison:Long and narrow leaves similar to the present specimen have been known in the genus *Nilssonia*, *Taeniopteris*, and *Nilssoniopteris* in Mesozoic plants. Leaves of these three genera have numerous secondary veins from the midvein. The leaves of the present specimen, however, do not have any secondary vein. Compared with these three genera, the midvein of the leaves of the present specimen are quite strong compared with its width.

Taeniatus elongatus Takimoto, Ohana and Kimura

Plate XXII, 1

Material: Holotype 00108-376-024G (housed in the Minamisoma Museum)

Locality: Shidazawarindo, Haranomachi Ward, Minamisoma City, Fukushima Prefecture.

Strata: Tochikubo Formation (Oxfordian), Somanakamura Group.

Description

Leaves at least 10 in number. Leaves long and narrow; 15-20 cm long, more than 1 cm wide, with a strong midvein and several weak veins. Margins strongly reflexed. A petiole-like base preserved in some leaves and with an abscission layer-like tissue. Cuticle and reproductive organs not preserved.

Remarks

This new species has a distinctive feature and similar ones have not been reported. Only *Nilssonia schaumburgensis* bears certain similarity in appearance to the present specimen. There is, however, a clear distinction between this plant and *Nilssonia schaumburgensis.* This plant has no secondary vein, while *Nilssonia schaumburgensis* has numerous secondary veins at right angles from midvein. The lengths to the width of leaf blades in this species is too long compare with that of *Nilssonia schaumburgensis*. (Takimoto et al., 2008)

Form-genus ***Taeniopteris*** Brongniart, 1828

Taeniopteris somaensis Takimoto, Ohana and Kimura

Plate XXII, 2

Material: KHFM-210034 (Holotype).

Locality: Tatenosawarindo, Kashima Ward, Minamisoma City, Fukushima Prefecture.

Strata: Tochikubo Formation (Oxfordian), Somanakamura Group.

Diagnosis: *Taeniopteris*-type leaves, large in size and spirally fasciculate with undulate margins.

Description

Leaves are oblanceolate, large-sized, more than 19 cm long, with rounded apices, not emarginate, cuneate proximally, and width of 7 cm at the middle. Rachises are slender, from which originate parallel veins. Margins are irregularly undulated. Veins are crowded, attached right angles to rachis or slightly oblique with density 18 per cm. Leaves are spirally fasciculated and four leaves are preserved (arrows) in this specimen, but their common point of emergence is missing. These leaves are probably disposed spirally in fascicular fashion.

Discussion

The present specimen is characterized by large-sized

Taeniopteris-type leaves, which are different from any other species of *Taeniopteris* in its distal shape near the apex and undulate margins. Four leaves appear to emerge from the common point in fascicular fashion. This fascicular fashion is never overlooked, however, the common point is missing. Since the leaf size varies, the leaves are considered to be spirally attached and developed in order. On the basis of the above-mentioned features, Takimoto et al. (2008) proposed the species name *Taeniopteris somaensis* sp. nov.

Taeniopteris-type leaves have been known as ferns (e. g. *Angiopteris*, Marattiaceae ; *Asplenium nidus*, Aspleniaceae), Pteridosperm (*Rhabdotaenia*), bennettitalean (*Nilssoniopteris*), Pentoxylean (*Nipaniophyllum*), and Cycadalean (*Nilssonia* with entire margins). It is difficult to know the affinity of the *Taeniopteris*-type leaves without preserved cuticle and reproductive organs. (Takimoto et al., 2008)

Genus ***Pelourdea*** Seward em, Ash, 1987

Pelourdea Seward, 1917

Discussion

The genus *Pelourdea* was established by Seward (1917) for Mesozoic *Cordaites*-like leaves in places of *Yuccites* and *Cordaites* on the bases of large strap-like leaves with parallel margins and longitudinally crowded veins. Later, Ash (1987) gave the emended diagnosis based on the specimens from the Triassic of North America as follows; plant short; stem erect, unbranched, narrow, bearing leaves in a helix. Leaves lanceolate to linear lanceolate, margins entire, apex acute to acuminate, base narrowing slightly to clasp stem; veins radiating from base, generally parallel, ending in lateral margins and apex. Ash (1987) described that *Pelourdea* can be definitely distinguished from other *Cordaites*-like leaves only if the clasping base. The original description of the genus *Pelourdea* by Seward (1917), however, shows that the existence of broad crescentic base. The mode of attachment of leaves to the stem not so clasp judged from the reconstruction of *Pelourdea*.

Under the circumstances, I adopted the generic name of *Pelourdea* to the present specimens after original description by Seward (1917).

Type species:*Pelourdea vogesiaca* (Schimper and Mouget) Seward, 1917.

Pelourdea nipponica Takimoto, Ohana and Kimura

Plate XXII, 3, 4; Figure 31

Zamites sp. cf. *Z. megaphyllus* (Phillips) Seward : Kimura and Ohana, 1988b, p. 121, pl. 6, Figure 1 ; pl. 7, Figures 1-2: Kimura and Ohana, 1989a, p. 13, pl. 3, Figure. 3 Kimura et al., 1991, p. 22, Figure 26.

Zamites sp. C: Kimura and Ohana, 1989a, p. 14, pl. 4 Figure 4 ; text-Figure 15.

Material: Holotype; KHFM-210032, Paratype; KHFM-210033

Type locality: Karamatsurindo minamishisen 2 , Kashima Ward, Minamisoma City, Fukushima Prefecture.

Strata: Tochikubo Formation (Oxfordian), Somanakamura Group.

Diagnosis

Leaves sessile, strap-shaped or elongate oblanceolate, varying in size, tapering gradually to acute to acuminate apex, and broad, more or less contracted proximally with broad crescent base.

Leaf blade thick and fleshy, more or less concave adaxially and convex abaxially in transverse sectional view. Leaf blade easily bursting longitudinally and easily tearing transversely. Veins numerous, parallel to leaf margins, 10-13 in number per cm at the middle part of each blade. Mode of attachment of leaf blade to the stem uncertain.

Description

Many detached thick and fleshy leaf blades have been collected at the Koyamada plant-site. Leaf blade is sessile, variable in size and generally parallel-sided; the broadest one in our collection is 6.8 cm wide (Plate XXIII) and the narrowest one is 1.2 cm wide (Plate

XXIII.E), except for its distal part. The preserved blade is 26.5 cm long (Plate XXIV.N). The whole shape of blade is unknown. The narrow blade of apical part is awl-shaped (Plate XXIII,.F,G,H), but occasionally obtusely pointed (PlateXXIV,.M) and the broad blades of proximal part are more or less contracted with a broad, crescent-shaped base, 3 cm wide and 0.5 cm high, which is considered to be a deciduous scar of leaf-base

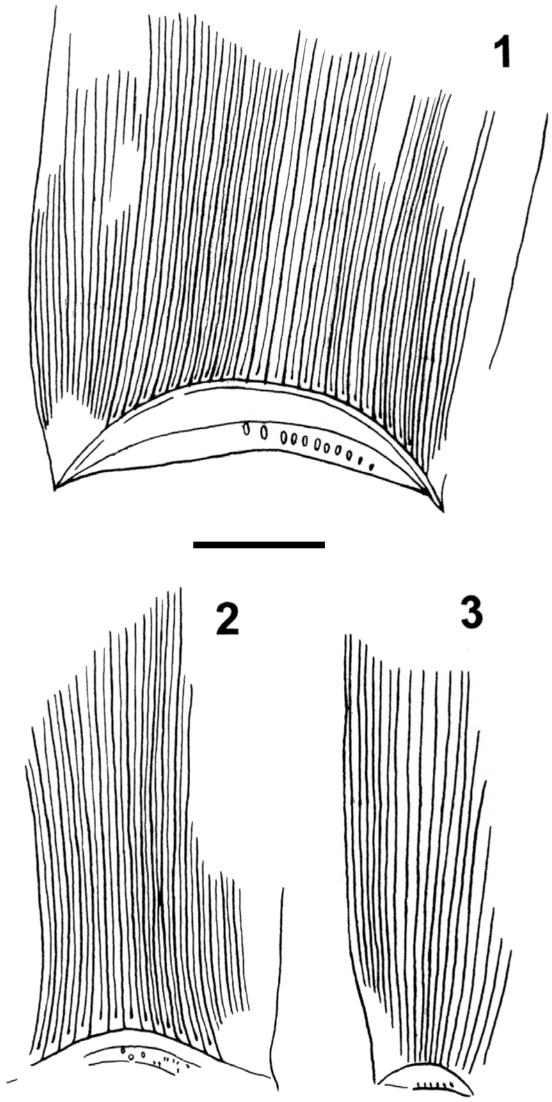


Figure 31. *Pelourdea nipponica*. **a.** (KHFM-210032, holotype)**b, c** (KHFM-210033, paratype) after Takimoto and Ohana (2008)

(holotype). Leaves seem to be little clasp to the stem because of the shape of leaf base.

The present blade is not flat but more or less concave adaxially (Plate XXIII,.A, C) and convex abaxially (Plate XXIII,.D, G, H) through out the blade. The blades appear to be easily burst longitudinally and to be easily torn transversely (Plate XXIV,.P).

Veins are numerous, parallel, 10-13 per cm in number in each blade (Figures 10-1,2,3). Accordingly, the vein density is coarse in the broad portion and crowded in the narrow portion of the blade. Interstitial veins are present between thick veins.

Stem and whole shape of this plant are unknown.

Discussion and comparison

Many detached and broken leaf-fragments were obtained from the Koyamada fossil site. They appear to be herbaceous and fleshy, and not woody. These fragments were described by Oishi (1940), Oyama (1954), Kimura and Ohana (1988a, 1989a), and Kimura et al.(1991) under the name of Cf. *Zamites megaphyllus* (Phillips), *Zamites* sp. cf. *Z. megaphyllus* (Phillps), and *Z.* sp. C. In our opinion the present plant is not the bennettitalean genus *Zamites*, because *Zamites* leaves are not represented by the leafy-shoots but pinnate. Therefore, the name of *Zamites* for the present plants should be revised.

Similar leaves to the present leaves were described by the previous authors, such as unsuitable *Yuccites*, which reminds us of the monocot genus *Yucca*. These leaves are also assigned by another author to the Paleozoic genus *Cordaites*. Seward (1917) established the new genus *Plourdea* for these leaves of which Mesozoic *Cordaites*-like leaves.

Pelourdea has been known from the Triassic of Europe (Seward, 1917), North America (Ash, 1987), and Middle Jurassic - Lower Cretaceous of the Northern Hemisphere. Person and Delevoryas (1982) described a single leaf-fragment from the Middle Jurassic of Oaxaca under the name of *Pelourdia* [sic] sp. This is the first occurrence of *Pelourdea* with thick crescent shaped leaf base and interstitial veins between thick veins.

Some paleobotanists suggested that *Desmiophyllum* is a more appropriate in place of *Pelourdea*. Our material, however, is quite different from *Desmiophyllum*, because the latter leaves are oblanceolate with contracted base.

Stopes and Fujii (1910) described a strap-shaped leaf fragment as *Niponophyllum cordaitiforme* from the Upper Cretaceous of Hokkaido, Japan. This fragment reminds us of narrow-type of *Pelourdea* blade. It is, however, difficult to give its systematic affinity because of the lack of evidence for example reproductive organ or cuticle.

Pelourdea resembles the detached leaves of *Heidiphyllum* (Retallack, 1981a), known from the Triassic of the Southern Hemisphere, however, *Heidiphyllum* is distinct from *Pelourdea* in the presence of plural interstitial veins between thick veins and extremely narrow leaf base (Anderson J. M. and Anderson H. M., 1989). (Takimoto et al., 2008)

Chapter 5
Floristic compositions

Characteristics of the plant-assemblage from the Somanakamura Group and paleoenvironment

In this study, I dealed with about 3,000 plant fossils and recognized 58 species belonging to 31 genera . Some of the constituents of the flora have been reported as new genera and new species. The fossil plant assemblage from the Somanakamura Group becomes one of the largest paleobotany collections in Japan. Characteristics of this flora are as follows:

Ferns

Ferns are the most abundant group in the flora. The ultimate pinnules of the ferns, for example *Eboracia microlobifolia*, *Cladophlebis matonioides*, *Sphenopteris* sp. B, are rather small compared to ferns of other Mesozoic ferns in Japan; in addition, the fern fronds commonly are tripinnate or quadripinnate. Based on those features, the fern fronds can be interpreted as parts of large-sized tree fern. Most of the extant tree ferns occur in tropical climate.

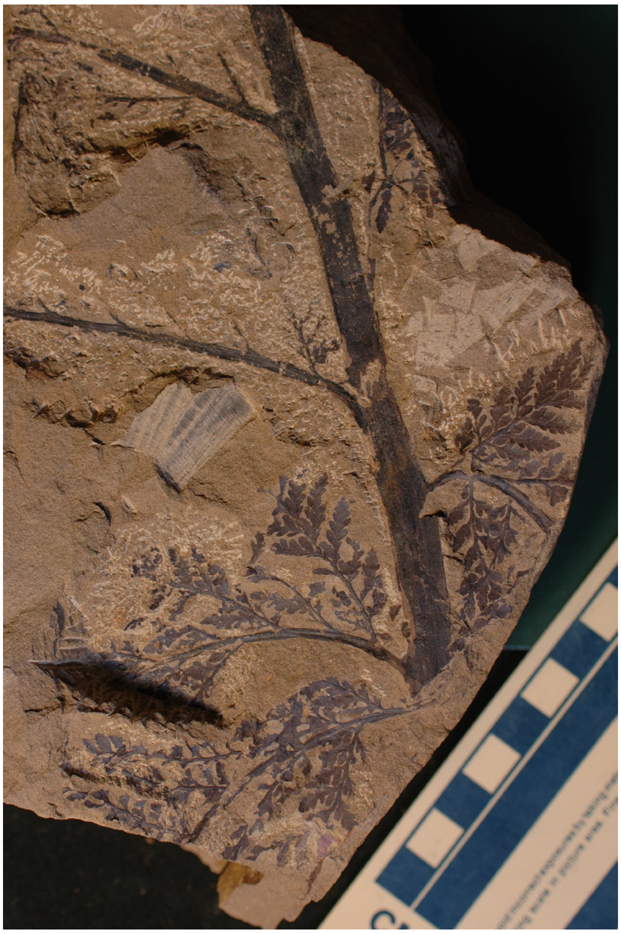


Figure 32. *Sphenopteris* sp B (SDS'05-234). large size tree fern with small pinnules.

Three species are present that show great close affinities to extant plant taxa. They are single species of Gleicheniaceae, Matoniaceae and Dicksoniaceae. The extant species of Gleicheniaceae and Dicksoniaceae occur today in Japan, however Matoniaceae are today not occurring in Japan but restricted to portions of southeastern Asia. Extant four species belonging to two genera in Matoniaceae are distributed in the Malay Peninsula, Borneo and New Guinea. The occurrence of matoniaceous ferns in this flora, therefore, indicates a condition of a tropical climate.

Bennettitales

The flora is characterized by an abundance of *Zamites* and *Ptilophyllum*, which account for 30 percent of the total specimens from the Somanakamura Group.

Bennettitales is an order of extinct plants, which occurred globally during the Mesozoic but became extinct during the Cretaceous. Although some bennettitalean leaves closely resemble those of cycads, they can be distinguished on the basis of their venation patterns as well as cuticular characters. The most abundant genus *Ptilophyllum* was occurred from southern part in China (Saiki and Wang, 2003).

Cycadales

Cycadalean *Nilssonia* leaves are various and abundant. One of the characteristic cycadalean foliages is *Nilssonia schaumburgensis*-type, with peculiar shaped foliage is typical in the Ryoseki-type (or Wealden-type) floras of the Late Jurassic–Early Cretaceous. Living cycadaleans are mainly restricted in dry, tropical areas (between 35° S and 35° N) such as in southeast Africa, Australia, and South and Central America.

Table 3 List of the fossil plants specimens from the Somanakamura Group.

Order	Family	No.	species
Lycopodiales	Lycopodiaceae	1	Lycopodites sp.
Equisetales	Equsetaceae	2	*Equisetites* sp.
		3	*Neocalamites* sp.
Filicales	Gleicheniaceae	4	*Gleichenites* sp. A
	Matoniaceae	5	*Matonidium* ex gr. *goepperti*
	Dicksoniaceae	6	*Eboracia microlobifolia*
	Unclassified ferns	7	*Onychiopsis elongata*
		8	*Onychiopsis yokoyamai*
		9	*Adiantopteris* sp.
		10	*Acrostichopteris* sp. A
		11	*Acrostichopteris* sp. B
		12	*Cladophlebis acutipennis*
		13	*Cladophlebis* sp. cf. *C. matonioides*
		14	*Cladophlebis* sp. cf. *C. vieginiensis*
		15	*Cladophlebis* sp. A
		16	*Cladophlebis* sp. B
		17	*Cladophlebis* sp. C
		18	*Cladophlebis* sp. D
		19	*Cladophlebis* sp. E
		20	*Cladophlebis* sp. F
		21	*Sphenopteris elegans*
		22	*Sphenopteris* sp. A
		23	*Sphenopteris* sp. B
Caytoniales	Caytoniaceae	24	*Sagenopteris* sp.
		25	*Caytonia* sp.
Bennettitales	Williamsoniaceae	26	*Otozamites* sp. cf. *kondoi*
		27	*Zamites brevipennis*
		28	*Zamites nipponicus*
		29	*Zamites* sp. A
		30	*Zamites* sp. B
		31	*Ptilophyllum jurassicum*
		32	*Ptilophyllum linearifolium*
		33	*Ptilophyllum* sp. cf. *oshikaense*
		34	*Ptilophyllum* sp. F
		35	*Ptilophyllum* sp. G
		36	*Ptilophyllum* sp. H
		37	*Nipponoptilophyllum bipinnatum*
		38	*Weltrichia* sp. A
		39	*Weltrichia* sp. B
		40	*Weltrichia* sp. C
		41	*Williamsonia* sp.
Cycadales	Nilssoniaceae	42	*Nilssonia* sp. cf. *N. Canadensis*
		43	*Nilssonia* sp. cf. *N. densinervis*
		44	*Nilssonia longipinnata*
		45	*Nilssonia oblique-truncata*
		46	*Nilssonia* ex gr. *Schaumbuegensis*
		47	*Nilssoniocladus tairae*
		48	*Nilssoniocladus japonicus*
	Unclasified cycadaleans	49	*Pseudoctenis* sp. A
		50	*Cycadites* sp.
		51	*Encephalartites nipponensis*
Coniferales	Unclasified conifers	52	*Elatocladus* sp. A
		53	*Pagiophyllum* sp.
		54	*Parasequoia* sp. cf. *P. cretacea*
Unclasified plants	Unclasified leaves	55	*Taenoatus elongatus*
		56	*Taeniopteris somaensis*
		57	*Peloudea nipponica*
	Unclasified seed	58	*Carpolithes* sp. A

They are relicts of a group that was widespread and diverse in the past, especially in the Mesozoic.

Conifers

Conifers are rather rare in this flora, but the presence of *Parasequoia* is distinctive.The genus was established by Krassilov (1967) from the Lower Cretaceous of Southern Primorye. *Parasequoia* is very close to the extant genus *Metasequoia*. It is impossible to distinguish these two genera by superficial morphology alone. The extant species *Metasequoia glyptostroboides* (Dawn Redwood) lives in wet areas, but in their native habitat, the plants also tolerate dry soils.

Late Mesozoic floras and phytogeography in Eastern Eurasia

Ohana and Kimura (1995) concluded that the Jurassic and Cretaceous floras in eastern Eurasia can be divided into the Ryoseki-type, the Tetori-type and the Mixed-type floras based on their species content. A simplified distribution of these floras is briefly shown in Figure 33. The Siberian-type flora is characterized by the rarity of bennettitalean and cycadalean taxa. The Ryoseki-type flora flourished under tropical or subtropical condition with a long arid season each year, and the Tetori-type flora developed under temperate and moderately humid climate. The Mixed-type flora is represented by a predominant Ryoseki-type assemblage and secondarily by Tetori-type taxa. The Mixed-type flora is distributed between the floristic territories of the Ryoseki-type and Tetori-type floras during the Early Cretaceous, but subsequently its distribution area tends to be expanded northward with time. The differences of taxa between the Ryoseki-type and the Tetori-type are described below and in table 4.

(1) The Matoniaceous ferns are dominant in the Ryoseki-type flora. The Dicksoniaceae ferns, which are characteristic of the Tetori-type, are

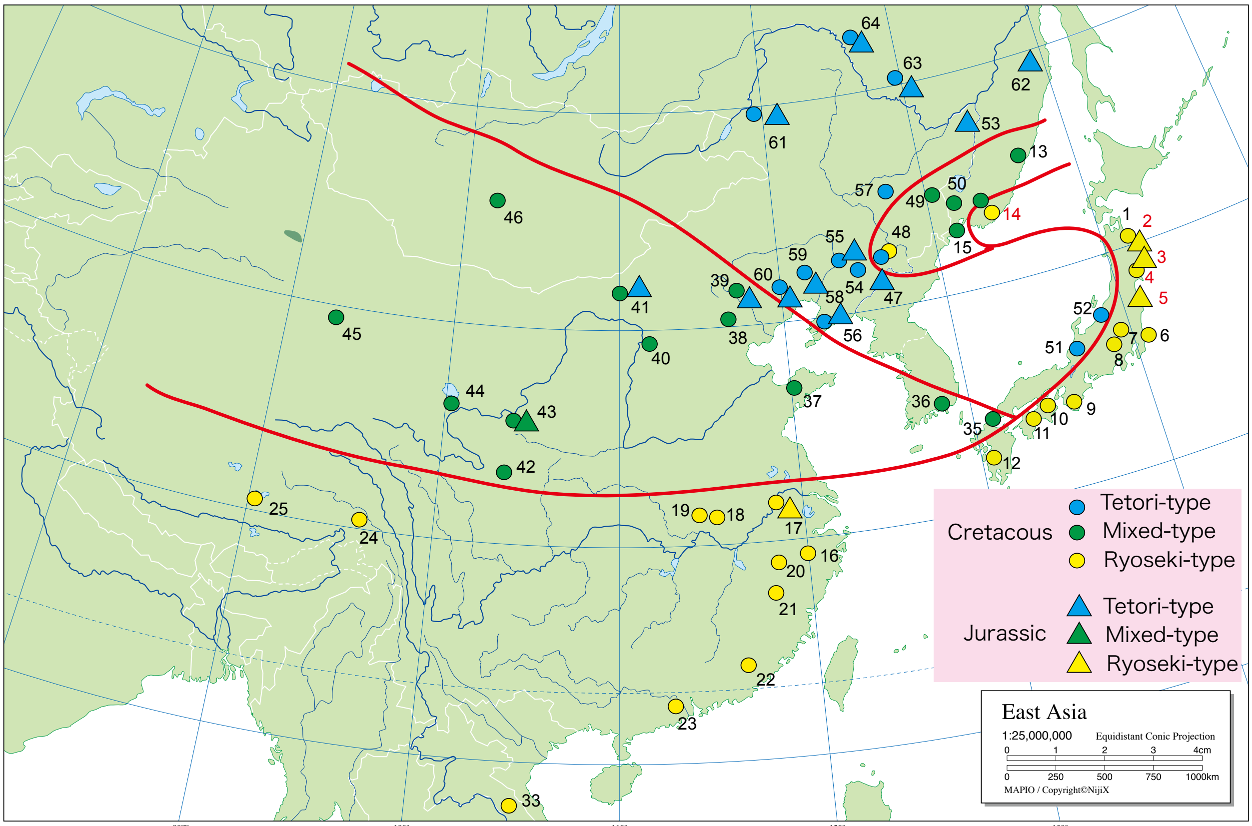


Figure 33. Localities of Late Jurassic and Early Cretaceous plants in East Asia with the phytogeography of tese periods. (from Kimura, 1987b). 1. Omoto (Omoto F.), Iwate Prefecture. 2. Karakuwa Peninsula and Oshima Island (Mone and Kogoshio F.), miyagi Prefecture. 3. Base of Oshika Peninsula (Oginohama F.), Miyagi Prefecture. 4. Tip of Oshika Peninsula (Ayukawa F.), Miyagi Prefecture. 5. Soma (Tochikubo F., Somanakamura G.), Fukushima Prefecture. 6. Choshi Peninsula (Choshi G.), Chiba Prefecture. 7. Kwanto Mountains (Sebayashi and Ishido F.), Gunma Prefecture.8. Todai, Akaishi Mountains (Todai F.), Nagano Prefecture. 9. Aridagawa Valley (Yuasa, Arida and Nishihiro F.). Wakayama Prefecture. 10. Latsuragawa Valley (Tatsukawa, Hanoura and Hoji F.), Tokushima Prefecture. 11. Monobegawa Valley, Kochi city and its neibouring area and Sakawa Basin (Ryoseki, Lower Monobegawa and Upper Monobegawa F.), Kochi Prefecture. 12. Middle Kyushu (Kawaguchi and Yatsushiro F.), Kumamoto Prefecture. 13. Central Shikhote-Alin. 14. Suchan Basin and eastern coast of Ussuri Bay 15. Suifun Basin. 16. East Zhejiang (Guantou and Moshishan F.). 17. Wuhu-Nanjing along the Yangzi River (Zihengshan, Yungeshan and Gecum F.) 18. Central Anhui (Zhanquio, Shuangmiao, Fuhsan and Yangwan F.). 19. Northern slope of the Dabie Mountains (Heishidu and Baidafan F.), SE-Henan and Anhui. 20. West Zhejiang and South Anhui (Laocun, Huangjian and Shouchang F.). 21. Fujian (changlin, Nanyuan and Bantou F.). 22. East and South Guandong (Gaojiping F. and Guancaohu and Baizushan G.). 23. West Guandong and Pingnam and Jinji Basins, Guangxi (Luoding F.). 24. Changdu, East Xizang (Duoni F.). 25. Lasa (Lhasa), Xinzang (Linbazong F.). 26. Trang South Thailand. 27. Gangau, Malaysia. 28. Maran, Malaysia (Smiley, 1970). 29. U1 Endau, Malaysia. 30. Panti, Malaysia. 31. Bintan Islans. 32. Tho Lam, South Viet Nam. 33. Saravanne, Laos. 34. Phnom Sangker, Cambodia. 35. Toyora District (Kiyosue F., Toyonishi G.), Yamaguchi Prefecture. 36. Gyeongsang-nam-do (Nagdong F., Lower Gyeongang SG.), South Korea. 37. Shandong Peninsula (Laiyang F.), Shandong. 38. Xihsan (Xiazhuang, Lushangfen and Tuoli F.), West Beijing. 39. North Hebei (Qinshila, Jiufotang, Zhanjiagou, and Houcheng F., Luanping G.). 40. North Shanxi and Neimeng (Zuoyun, Xiaying and Houbaiyinbulang F.). 41. Guyang Basin, Yinshan, Central Neiming (Guyang, Lsangou and Daqingshan F.). 42. North Qinling Mountains, South Gansu (Donghe G.). 43. Ordos Basin (Ningxia) Zhidan and Liubanshan G.) (Huang, Z. G.). 44. East Qilianshan Mountains, East Qinghai (Hekou G.). 45. West Qilianshan Mountains, West Gansu (Simminbo and Chijinbao F.). 46. East, Central and West Mongolia. 47. Yanbian District, Southeast Jilin (Tuntianying, Xishanping, Chanfcai, Tongfosi and Dalasi F.). 48. Dongning Basin, South Heilonjijang (Dongning F.). 49. Jixi, Boli and Shuangyashan Basins, Heilongjiang (Didao, Shihebei, Chenzihe, Muling, Dongshan and HOushigou F.). 50. South Khanka Lake. 51. Tetori Basin, Ishikawa, Fukui, Nagano and Gifu Prefevture. 52. Tokura (Tokurazawa F.), Gunma Prefecture. 53. Wandashan Mountains, Heilongjiang (Chaoyangtun and Yunshan F., Longzhaogou G.). 54. Jiaohe District, eastern part of Jilin City (Moshilaza F. and its equivalent). 55. Southern part of Sunliao District, Jilin (Huoshiling, Shahezi, Yingcheng and Denglouku F.). 56. Liaoyuan Basin and its surrounding areas, Central Jilin (Jiude, Anmin and Changan F.). 57. Western Zhangguancailing Mountains, Binxain, Heilongkiang (Taoqihe F.). 58. East Liaoning (Xiaodonggou, Xiaoling and Lishigou F.). 59. Fuxin and Yixian Districts, West Liaoning (Yixan, Sashai, Haizhou and Sunjiwan F.). 60. Western border of Liaoning (Yixian, Jiufotang and Binggou F.). 61. Western Daxinganling Mountains, North Neimeng (Daxinganling and Zhalainuoer G.). 62. Aniui. 63. Bureja Basin. 64. Zeia Basin. 65. Priokhotie. 66. Stanovoy Mountains. 67. Tokin Basin. 68. Upper course of the Aldan. 69. Magadan. 70. Anadyr. 71. Kresta Bay. 72. Zyrianka Basin. 73. Novosibirsk Islands. 74-77. Lena Basin. 74. Lower course of the Lena and Olenek. 75. Middle course of the Lena. 76. Vilui. 77. Aldan. 78. Khatanga. (26-32, 65-78 not included in this map)

only known from the northern part of the Ryoseki-type floras. Generally, ferns of the Ryoseki-type flora have entire-margin and small pinnae.

(2) The bennettitaleans are diverse and abundant in each floral type. The genera *Zamites* and *Ptilophyllum* characterize the Ryoseki-type flora. Both genera have never been found in the Tetori-type flora; instead the genera *Neozamites* and *Dictyozamites* characterize the Tetori-type flora.

(3) The cycadaleans are not very diverse in both floras. The representative genera include *Ctenis*, *Pseudoctenis* and *Nilssonia*. The genus *Ctenis* has never been found in the Ryoseki-type flora. Two types of *Nilssonia* leaves are known in the Ryoseki-type flora. One type has a coriaceous, long lamina, another has a wide lamina with long and narrow pinnae. *Nilssonia* leaves in the Tetori-type flora are oblanceolate or elliptic in shape. The lamina of their leaves is irregularly lobed and the lobes are serrated.

(4) Many genera of Ginkgophyta are known from the strata of the Mesozoic Era all over the world. Typical genera are *Ginkgo*, *Ginkgoites*, *Baiera*, *Sphenobaiera*, *Ginkgoidium*, and *Pseudotorellia*. However, no Ginkgophyta representative occurs in the Ryoseki-type flora. Those genera are quite abundant in the Tetori-type flora.

(5) The Czekanowskiales have been discovered only from the Tetori-type flora, which otherwise have been described throughout the Northern Hemisphere. Czekanowskiales are characterized by bundle of linear leaves attached on short shoots surrounded by scale like leaves (bachiblast). Leaves are divided dichotomously. They include *Czekanowskia*, *Phoenicopsis*, *Arctobaiera*, *Solenites*, *Sphenarion*, etc. The reproductive organs of Czekanowskiales are quite different from those of Ginkgoales and Coniferales.

(6) The Coniferales are various and abundant throughout the Mesozoic Era. Two types of conifer leaves were recorded. Scale-like conifer leaves are only known from the Ryoseki-type flora, with genera such as *Frenelopsis*, *Pseudofrenelopsis*, *Cupressinocladus*, *Brachyphyllum*, *Pagiophyllum*, and *Geinitzia*. Needle-like conifer leaves are characteristic for the Tetori-type, excepting genera such as *Podozamites*. *Podo-*

Table 4. Difference in the composition of the flora between Ryoseki-type and Tetori-type

	Taxa, character	Tetori	Ryoseki	Soma
Filicales	*Raphaelia*	abundant		
	Dicksoniaceae	various	rare	rare
	Matoniaceae		abundant	abundant
	Weichselia		abundant	
Bennettitales	*Zamites*		various	various
	Ptilophyllum		various	various
	Neozamites	abundant		
	Dictyozamites	various		
Cycadales	*Ctenis*	abundant		
	Nilssonia (serrate margin)	abundant		
	Nilssonia (narrow strap-shaped leaf)		abundant	abundant
	Nilssonia (bload leaf)		abundant	abundant
Ginkgoales	*Ginkgo*, etc	abundant		
Czekanowskiales	*Phoenicopsis*, etc	abundant		
Coniferales	*Podozamites*	various		
	scale like leaves, Cheilolepidoaceae		various	various
	needle leaves	various		rare

zamites leaves have oblanceolate or elliptic leaves and they are characteristic of the Tetori-type flora. *Elatides* and *Parasequoia* also have needle-like leaves, however, they are known from the Ryoseki-type flora.

Recently several stratigraphic and paleobotanical studies (Yabe et al., 2003; Yabe and Kubota, 2004; Yamada and Uemura, 2008; Yamada, 2009) have challenged the concept of Kimura and coworkers (Kimura, 1958, 1979, 1987; Kimura and Sekido, 1976, 1978; Kimura and Ohana, 1997; Ohana and Kimura, 1995). Dealing with the relation between the geological time and the floristic changes during the Middle Jurassic to Early Cretaceous interval in Japan, Yamada (2009) suggested that the Ryoseki-type flora covered the entire Japanese territory during the Aptian due to climate warming at that time.

The Soma Flora

Here I propose the 'Soma Flora' for the plant assemblage from the Tochikubo and Tomizawa formations, Somanakamura Group. As I already illustrated the features of the Soma Flora and its composition, it belongs to the Ryoseki-type flora. It is important to note that the Soma Flora contains one of the largest number of specimens among the Ryoseki-type floras in Japan. Only one element of the Tetori-type; *Onychiopsis* sp. cf. *O. elongata*, is found from the Tithonian Tomizawa Formation, Somanakamura Group. However, I have a perception of that it evolved from *Onychiopsis yokoyamai* at the end of Jurassic, and it is unknown plant that completely same species with *Onychiopsis elongata* in the Tetori-type flora

It should be also stressed that common elements occur between the Soma Flora and the Early Cretaceous flora of Southern Primorye, for example *Matonidium goepperti*, *Nilssoniocladus* (Volynets, 2010) *Encephalartites*, *Parasequoia*, *Nilssonia* ex gr. *schaumbuegensis and Nilssonia densinervis.* The flora of Southern Primorye has more elements in common with the Soma Flora than the floras of the Outer zone in southwest Japan, according to this study. Detailed paleobotanical and geological comparisons between the Soma Flora and the flora of Southern Primorye are required. Yabe et al. (2003) deals with the floristic change in southern Primorye during the Early Cretaceous. Yabe et al. (2003) suggest that plate tectonics might explain the floristic change between the Ryoseki-type and the Mixed-type floras in southern Primorye.

The tropical elements of the Soma Flora were discussed in the previous section. The Matoniaceous ferns, tree ferns and Cycadales indicate a tropical climate. On the other hand, *Nilssonia* ex gr. *schaumbergensis, Zamites nipponicus, Sagenopteris* sp. and other species have clear abscission layers at their base of petiole (Figure 34). This feature is typical of plants with deciduous habit, which inhabited in cooler condition or those under other environmental stresses, like aridity. Taking into account of the occurrence of some genera possibly indicating a tropical climate, presence of short dry season would be more probable. This view is supported by Kimura et al., 1985 reported by other Ryoseki-type floras. On the contrary, however,

Legrand et al. (2011) discussed that the paleoclimate of the Ryoseki-type Choshi flora is not so arid but

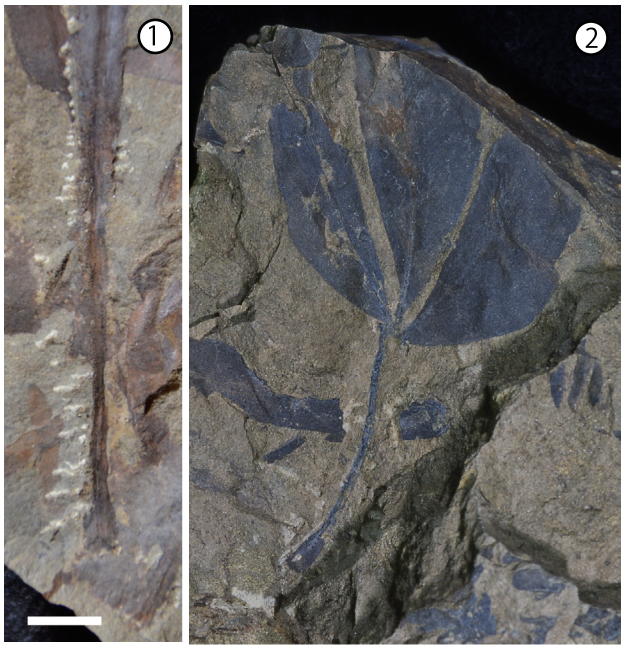
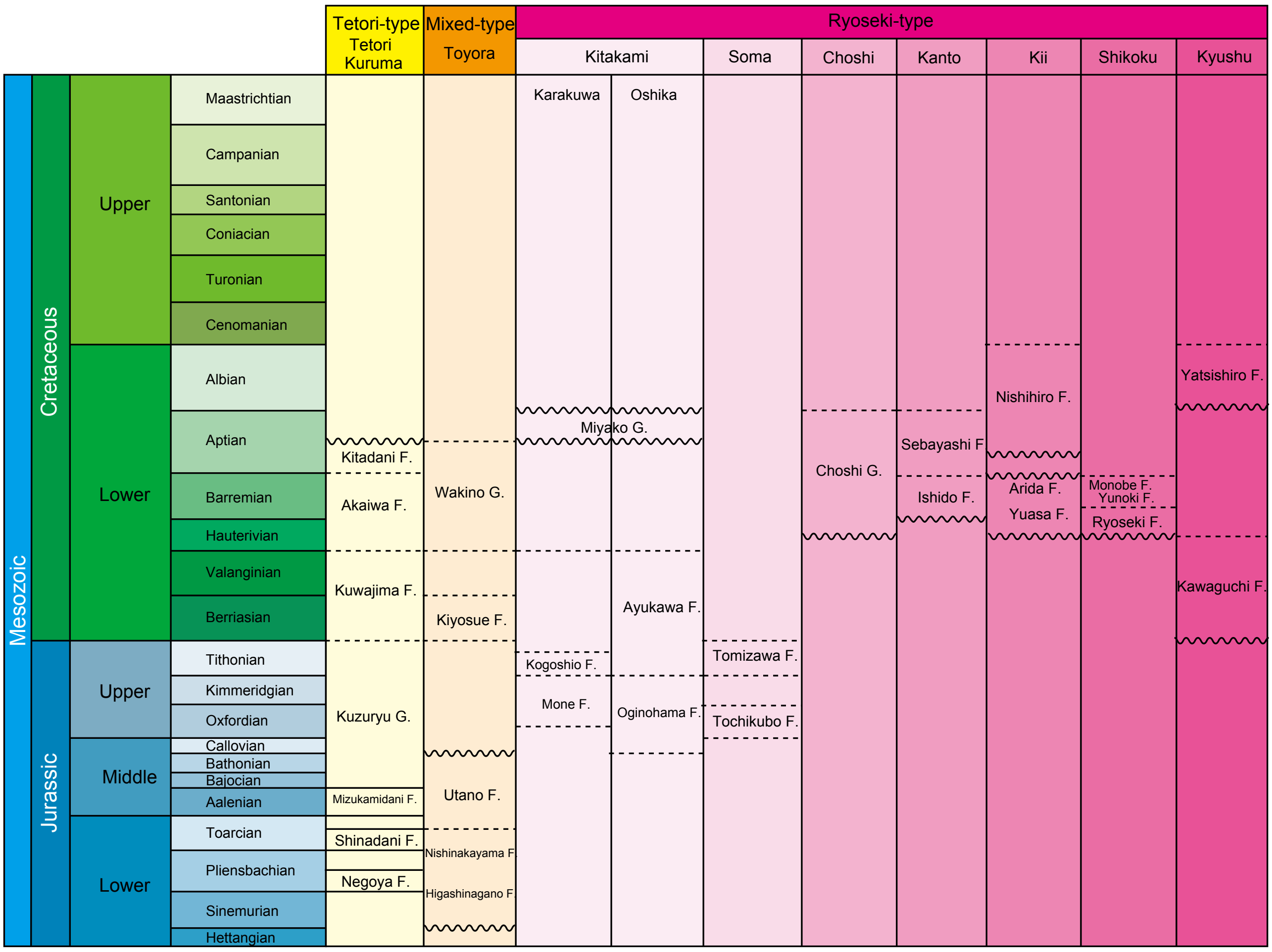


Figure 34. Abscission layers at the leaf base. 1. *Nilssonia* ex gr. *schaumbergensis*. 2. *Sgenopteris* sp.

comparatively wet, based on thorough palynological study. Palynological analysis for the Soma flora should be needed in future to better understand the dimension or temporal floral changes.

Table 5. Stratigraphical scheme of Jurassic-Early Cretaceous plant-bearing formations in Jpan.



Chapter 6
Discussions
The relation between Soma and South Kitakami

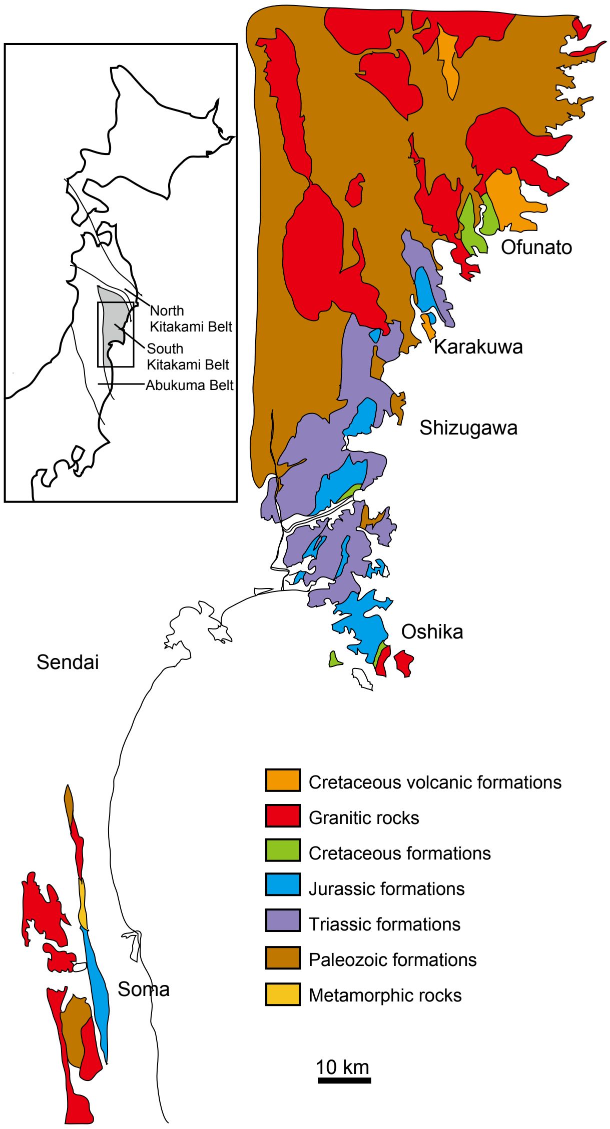
Takizawa (1985) concluded that the Jurassic to Cretaceous formations in the Middle Subbelt of South Kitakami are distiributed in three areas, the Karakuwa, Oshika and Soma aeas from north to south. Middle Jurasic to lowermost Cretaceous Shishiori Group and Lower Cretaceous Oshima Group are distributed in the Karakuwa area, northeastern Miyagi Prefecture. Oshika Group ranging from the Middele Jurassic to Lower most Cretaceous is distributed in Oshika peninsula, Miyagi Prefecture. The Somanakamura Group is located at the eastern margin of the Abukuma Mountains, 100 km far from the Oshika area. Howerver some studies have already suggested an obvious similarity between Soma and South Kitakami areas in geological and paleontological features.

Geology

Takizawa (1985) indicated a close affinity in Jurassic sedimentation between the South Kitakami Mountains and the Soma Area, along the eastern margin of the Abukuma Mountains. The Upper Jurassic–Lower Cretaceous strata in the Soma Area are similar to those of Karakuwa and Oshika groups (Kitakami proper) in sedimentary facies and sediments; therefore both area had the same provenance, sedimentary basin and hinterland.

Radiolarian fossils

Taketani (1987) and Nara et al. (1994) reported that the radiolarian assemblage of the Koyamada Formation, Somanakamura Group is very similar to that of the Isokusa Formation cropping out along the Nagasaki Coast in Oshima Island, Kesennuma City, Northeast Japan. The high similarity in radiolarian assemblages shows that the Koyamada Formation can



Fugure 35. Distribution of Mesozoic strata in the South Kitakami Belt. (modified from Takizawa, 1985)

be correlated with the Isokusa Formation. The radiolarian and ammonite assemblages of both formations represent elements exclusively of the Tethyan Pacific biogeographic province of low to middle latitude. Both formations belonging to the South Kitakami Belt. The sedimentary basin of the South Kitakami Belt surely occurred in the province during the early Cretaceous (Taketani, 2013).

Ammonites

Ammonites' fauna of the Nakanosawa Formation show Tethys–Pacific affinities. There are no Arctic elements in this fauna. *Aulacosphinctoides*, *Subdichotomoceras* and *Pachysphinctes* of the subfamily Virgatosphinctinae are frequent in the Cutch and Himalayan areas, as well as in the Submediterrranean Region, including Madagascar, Kenya, North Africa, and South Europe. Some of these Submediterranean elements extend further eastward, passing Southeast Asia and Japan, reaching Middle and South America. This is consistent with other elements such as *Hybonoticeras* and *Aspidoceras*, which are widely known from the Tethys Sea. Although *Holcophylloceras* has a worldwide distribution, it is frequent in the Pacific, including in the Japanese Jurassic (Sato and Taketani, 2008).

Plant fossils

Kimura et al. (1990) discussed the features of the Late Jurassic floras in the Outer Zone of northeast Japan. They reported 79 species belonging to 30 genera from the Somanakamura, Oshika and Shishiori groups, which they regarded all to belong to the Ryoseki-type flora.

Upon a current analysis, I recognized 100 species belonging to 38 genera from the Somanakamura, Oshika and Shishiori Groups. Among them, nine species are common in all three localities and eight species are common between the Soma and South Kitakami areas. Based on careful reexamination of those common species, the floras of Somanakamura, Oshika and Shishiori groups have the following features in common.

Common species in the Soma, Oshika and Karakuwa area

(1) *Onychiopsis yokoyamai*

Onychiopsis yokoyamai was originally described by Kimura and Aiba (1986) from the Lower Cretaceous Hoji Formation at Furuke, Katsuragawa district, Tokushima Prefecture. More than ten specimens of this species were obtained from each group. *Onychiopsis yokoyamai* is one of the common elements of the Late Jurassic–Early Cretaceous Ryoseki-type flora.

(2) *Cladophlebis* sp. cf. *C. viginiensis*

Cladophlebis viginiensis is well known from the Lower Cretaceous of North America (Fontaine, 1889; Bell, 1956, etc). This species is frequent in the Somanakamura and Oshika groups, and rare in the Shishiori Group.

(3) *Zamites nipponicus*

Zamites nipponicus was originally described by Kimura and Ohana (1988b) from the Upper Jurassic Tochikubo Formation. Many fossils of *Zamites nipponicus* also occur in the Oginohama Formation, Oshika Group at Samenoura. Ishinomaki City, Miyagi Prefecture. Several specimens were found in the Mone Formation, Shishiori Group, in two localities, Kesennuma City, Miyagi Prefecture. This species is the only known taxon from the Somanakamura, Oshika and Shishiori groups therefore it is regarded as an index or characteristic species in these areas. Recently, numerous leaves of *Zamites nipponicus* were obtained from the Tochikubo Formation at the highway construction site. Many excellent specimens such as a complete leaf, reproductive organs and several leaves attached to the stem were found. Therefore, a reconstruction of this plant is now underway together with my colleagues.

(4) *Ptilophyllum linearifolium*

Ptilophyllum linearifolium was originally described by Kimura and Ohana (1989). The holotype and the paratype of this species were from the Lower Cretaceous Monobegawa Formation, at Higashikuma, Kochi City, Kochi Prefecture. Some specimens from the Upper Jurassic Oginohama Formation, Oshika Group and the Upper Jurassic Mone Formation, Shishiori Group were identified as this species in the same paper. Recently, I found several specimens of *Ptilophyllum linearifolium* from the Upper Jurassic Tochikubo Formation, Somanakamura Group in the collection of the Fukushima Museum. The leaf fragment regarded by Oishi (1940) as *P. pecten* from the Lower Cretaceous Yuasa Formation, Wakayama Prefecture should identify as this species.

(5) *Ptilophyllum oshikaense*

Ptilophyllum oshikaense was originally described by Kimura and Ohana (1989) from the Upper Jurassic Oginohama Formation, Oshika Group at Samenoura, Ishinomaki City, Miyagi Prefecture. This species was also reported from the Tochikubo Formation in the Somanakamura Group and the Kogoshio Formation in the Shishiori Group, though it is uncommon in occurrence in the Soma flora.

(6) *Nilssonia* sp. cf. *N. densinervis*

Nilssonia densinervis (Fontaine) was described by Krassilov (1967) from the Lower Cretaceous of Southern Primorye. This type of leaves has been recorded from the Upper Jurassic–Lower Cretaceous plant-beds in the Outer Zone of Japan.

(7) *Nilssonia* ex gr. *N. schaumburgensis*

This species first described as *Pterophyllum schaumbugense* from the Wealden of Germany (Dunker, 1846). Nathorst (1890) established *Nilssonia schaumburgensis* from the Ryoseki and Monobegawa Formation, Kochi Prefecture. Similar leaves have been described from the Lower Cretaceous of Northern Germany, England, North America, Southern Primorye, Southern Korea, Outer Zone of Japan and Upper Jurassic of Northeast Japan. *Nilssonia* s*chaumbuegensis*-type leaves are characteristic to the Ryoseki-type floras.

(8) *Parasequoia* sp. cf. *P. cretacea*

Parasequoia cretacea was established by Krassilov (1967) from the Lower Cretaceous of Southern Prumorye. This species is only known from these three groups in Japan.

(9) *Pelourdea nipponica* (*Zamites* sp. *Z. megaphyllus*)

Pelourdea nipponica was originally described by Takimoto et al. (2008) from the Tochikubo Formation, Somanakamura Group. This plant was described by Oishi (1940), Oyama (1954), Kimura and Ohana (1988a, 1989a) and Kimura et al. (1991) as *Zamites* sp. cf. *Z. megaphyllus* from the Upper Jurassic of Northeast Japan. *Pelourdea* has been recorded from the Triassic of Europe and North America and from the Middle Jurassic–Lower Cretaceous of the Northern Hemisphere.

Common species between Soma and South Kitakami (Oshika or Shishiori)

(1) *Matonidium* ex gr. *M. goepperti*

Matonidium goepperti was established by Schenk (1871) on the basis of the leaves from the Lower Cretaceous of North Geermany. Krassilov (1967) described *Matonidium goepperti* from the Lower Cretaceous of Southern Primorye on the basis of pinna fragment. The occurrence of this species from the Tochikubo Formation (Kimura and Ohana, 1988a) was the first record in the Japanese Mesozoic. After that, Kimura et al. (1990) described this species from the Mone Formation, Shishiori Grpup.

(2) *Eboracia microlobifolia*

This species was established and described by Kimura and Ohana (1988a) on the basis of the leaves from the Tochikubo Formation. This plant found from the lowermost Cretaceous Ayukawa Formation in the Oshika Group.

(3) *Cladophlebis acutipennis*

Cladophlebis acutipennis were described from the Tochikubo Formation, Somanakamura Group (Kimura and Ohana, 1988a) and the Oginohama Formation, Oshika Group (Kimura and Ohana, 1989). This species is commonly known from the Upper Jurassic–Lower Cretaceous plant beds in the Outer Zone of Japan.

(4) *Otozamites* sp. cf. *O. kondoi*

Oishi (1940) originally described *Otozamites kondoi* on the basis of several leaf-fragments from Oshima, Kesennuma City, Miyagi Prefecture. This plant described from the Tochikubo Fromation, Somanakamura Group (Kimura and Ohana a988a) and the Kogoshio Formation, Shishiori Group (Kimura et al., 1990).

(5) *Ptilophyllum* sp. G

This species were described from the Tochikubo and Kogoshio formations. Similar leaves have been described as other specific name of *Ptilophyllum* from the Upper Jurassic–Lower Cretaceous plant-beds in the Outer Zone of Japan.

(6) *Weltrichia* sp. D

The large-sized male bennettitalean reproductive structure with a large number of elongate rays was collected from the Upper Jurassic Tochikubo and Oginohama Formation.

(7) *Williamsonia* sp.

This female bennettitalean reproductive structure was collected from the Upper Jurassic Tomizawa and Oginohama formations.

(8) *Nilssonia* sp. cf. *N. canadensis*

Nilssonia sp. cf. *N. canadensis* was collected from the Upper Jurassic Tochikubo and Kogoshio Formation.

Table 6-1. Fossil plant-taxa recognized from the Upper Jurassic plant-bearing formations in the Outer Zone of Northeast Japan and their number of locallities and specimens.

	Plants	Soma				Oshika		Karakuwa			
		Tochikubo		Tomizawa		Oginohama		Kogoshio		Mone	
		Loc.	Spe.	Loc.	Spe.	Loc.	Spe.	Loc.	Spe.	Loc.	Spe.
Bryophyta	*Thallites* sp. A							1	2		
	Thallites sp. B							1	7		
Ferns	*Lycopodites* sp.	1	2								
	Equisetum sp. cf. *E. phillipsi*					1	9				
	Equisetum ? sp.									1	1
	Equisetites sp.	2	23								
	Neocalamites sp.	1	2								
	Todites sp.									1	11
	Gleichenites sp. A	2	16								
	Gleichenites sp. B					1	13				
	Gleichenites sp. C					1	24				
	Gleichenites sp. D							1	7		
	Matonidium ex gr. *goepperti*	2	43							1	10
	Coniopteris nipponica							1	15		
	Eboracia microlobifolia	3	525			1	32				
	Onychiopsis yokoyamai	3	13		5	1	10	1	13		
	Onychiopsis sp. cf.*elongata*	1	1								
	Adiantopteris oshimaensis							1	14		
	Adiantopteris sp.	1	1								
	Acrostichopteris sp. cf. *A. parvifolia*					1	2				
	Acrostichopteris sp. A	1	2								
	Acrostichopteris sp. B	1	11								
	Cladophlebis acutipennis	2	26			1	31				
	Cladophlebis sp. cf. *c. constricta*							1	3	1	2
	Cladophlebis geyleriana							1	4		
	Cladophlebis matonioides							1	16		
	Cladophlebis sp. cf. *C. matonioides*	2	9								
	Cladophlebis oshimaensis							1	19		
	Cladophlebis sp. cf. *C. vieginiensis*	2	107			1	31	1	1	1	1
	Cladophlebis sp. A	1	26								
	Cladophlebis sp. B	1	5								
	Cladophlebis sp. C					1	21				
	Cladophlebis sp. D							1	6	1	6
	Cladophlebis sp. E							1	3		
	Cladophlebis sp. F							1	5		
	Cladophlebis sp. G							2	4		
	Cladophlebis sp. H							1	5		
	Cladophlebis sp. I							1	3		
	Cladophlebis sp. J									1	6
	Sphenopteris elegans	2	23								
	Sphenopteris sp. A	1	1					1	6	1	6
	Sphenopteris sp. B	1	1			1	13				
	Sphenopteris sp. C	1	1								
	Sphenopteris sp. D	1	1								
Seed Ferns	*Sagenopteris* sp.	2	11								
	Caytonia sp.	1	5								

Table 6-2. Fossil plant-taxa recognized from the Upper Jurassic plant-bearing formations in the Outer Zone of Northeast Japan and their number of locallities and specimens.

	Plants	Soma				Oshika		Karakuwa			
		Tochikubo		Tomizawa		Oginohama		Kogoshio		Mone	
		Loc.	Spe.	Loc.	Spe.	*Loc.*	Spe.	*Loc.*	Spe.	*Loc.*	Spe.
Bennettitaleans	*Otozamites* sp. cf. *kondoi*	*4*	7					*1*	3		
	Otozamites sp. nov.	*1*	21								
	Zamites brevipennis	*1*	2								
	Zamites sp. *Z. choshiensis*					*2*	38	*5*	15	*1*	4
	Zamites densipinnatus					*2*	50				
	Zamites nipponicus	*2*	250			*1*	35			*2*	2
	Zamites sp. *Z. tosanus*					*1*	3	*1*	2		
	Zamites sp. A		1								
	Zamites sp. B		1								
	Zamites sp. C					*1*	3				
	Zamites sp. D					*1*	1				
	Ptelophyllum sp. A							*2*	8		
	Ptilophyllum jurassicum	*2*	183								
	Ptilophyllum linearifolium	*1*	7			*2*	35	*2*	2	*1*	1
	Ptilophyllum oshikaense	*1*	1			*3*	42	*1*	2		
	Ptilophyllum sp. F	*1*	3								
	Ptilophyllum sp. G	*2*	3					*2*	6		
	Ptilophyllum sp. H	*1*	4								
	Ptilophyllum sp. I							*1*	4		
	Nipponoptilophyllum bipinnatum	*1*	50								
	Weltrichia sp. A	*1*	1								
	Weltrichia sp. B	*1*	1								
	Weltrichia sp. C	*1*	1								
	Weltrichia sp. D	*1*	1			*1*	1				
	Williamsonia sp.	*1*	2			*1*	1				
Cycadaleans	*Pseudoctenis* sp. cf. *P. lanei*					*1*	4				
	Pseudoctenis sp. A	*1*	3								
	Nilssonia sp. cf. *N. Canadensis*	*4*	44					*1*	5		
	Nilssonia sp. cf. *N. densinervis*	*3*	26			*1*	8	*2*	6		
	Nilssonia longipinnata	*2*	29								
	Nilssonia sp. cf. *N. nigracollensus*							*1*	34		
	Nilssonia oblique-truncata	*1*	13			*1*	3				
	Nilssonia ex gr. *Schaumbuegensis*	*5*	188			*2*	35	*2*	42		
	Nilssonia sp. A							*1*	5		
	Nilssonia sp. B (sp.nov.)	*1*	3						5		
	Nilssoniocladus tairae	*1*	7								
	Nilssoniocladus japonicus	*1*	9								
	Cycadites sp.	*1*	10								
	Encephalartites nipponensis	*1*	14								
Conifers	*Elatocladus* sp. A	*2*	2								
	Elatocladus sp. B					*1*	4				
	Elatocladus sp. C							*1*	6		
	Frenelopsis sp. cf. *F. chosiensis*							*4*	53		
	Brachyphyllum sp. A							*1*	19		
	Cupressinocladus koyatoriensis					*2*	21			*1*	37
	Cupressinocladus sp. C					*2*	18			*2*	36
	Pagiophyllum sp.	*2*	14								
	Parasequoia sp. cf. *P. cretacea*	*4*	50			*1*	44			*1*	7
	New genus	*1*	21								
Unclassified plants	*Taenioatus elongates*	*1*	1								
	Taeniopteris somaensis	*1*	1								
	Taeniopteris sp. F					*1*	9				
	Taeniopteris sp.G							*1*	14		
	Pelourdea nipponica (*Zamites* sp. *Z. megaphyllus*)	*1*	40			*1*	38	*1*	1		
	Carpolithus sp.	*3*	25								

Total number of the common species 1783
Total numbers of the specimens 2975
Percentage of tahe common species 59.9%

Chapter 7
Conclusions

In this study, I thoroughly examined the fossil plants from the Upper Jurassic Tochikubo and Tomizawa formations in the Somanakamura Group and proposed here the Soma flora. All the species of the flora was identified, which accounts for 31 genera and 58 species. Some of the constituents of the flora have been reported as new genera and new species. The Soma flora became one of the best-studied floras among the Ryoseki-type floras in Japan based on huge number of materials. Floristic studies of the Soma flora itself as well as careful comparisons with the contemporaneous floras from the Oshika and Shishiori groups gave many insights into our understandings on the Late Jurassic floras in Japan and eastern Eurasia as followings.

(1) The flora of the Somanakamura Group

Ferns are the most abundant group in the flora. The ultimate pinnules of the ferns, such as common species *Eboracia microlobifolia* (525 specimens), are rather small compared to ferns of other Mesozoic ferns in Japan. *Matonidium* ex gr. *M. goepperti* has close affinities to extant plant taxa Matoniaceae.

Bennettitales are abundant in the collection. More than 500 leaf and reproductive organ fragments belongs to Bennettitales. Especially, *Zamites* and *Ptilophyllum* are very common.

The most common frond of Cycadales is *Nilssonia.* About 200 specimens from the five localities belong to *Nilssonia schaumbergensis. Nilssonia* of broad leaf; *N. Canadensis, N. densinervis* and others are also common.

Conifers are rare in the flora. The most common leaves are *Parasequoia* sp. cf. *P. cretacea* reported from the Lower Cretaceoous of Southern Primorye. Only 16 fragments of scale like leaves conifers were obtained.

The common elements in the Inner Zone of Japan; ginkgpalean, czekanowskialean, Podozamites, etc have not been found.

From the above plant assemblage, I concluded that the Late Jurassic flora from the Somanakamura Group belongs to the Ryoseki-type flora proposed by Kimura (1961, 1987a, 1987b, 1988). Several new elements: *Neocalamites*, *Nilssoniocladus*, *Encephalartites*, *Pelourdea* are added to the Ryoseki-type flora by this study.

(2) Paleoenvironment presumed by fossil plants

The plant assemblage of the Soma Flora indicate tropical climate with long arid season. The existence of Matoniaceae and large sized tree ferns indicate tropical climate. The Leaves of *Nilssonia schaumbergensis* and *Sagenopteris* sp. have abscission layers at the base of the petiole. This character indicates seasonality and might point an arid season.

(3) Comparison with the floras in South Kitakami

As a proved result, the Late Jurassic floras from the Somanakamura, Oshika and Shishiori groups have now many features in common. These three floras belong to the Ryoseki-type flora.

In this study, I also found many common elements between the floras of the Somanakamura and the Southern Primorye. The comparison between the Soma flora and the flora of the Southern Primorye area is requested.

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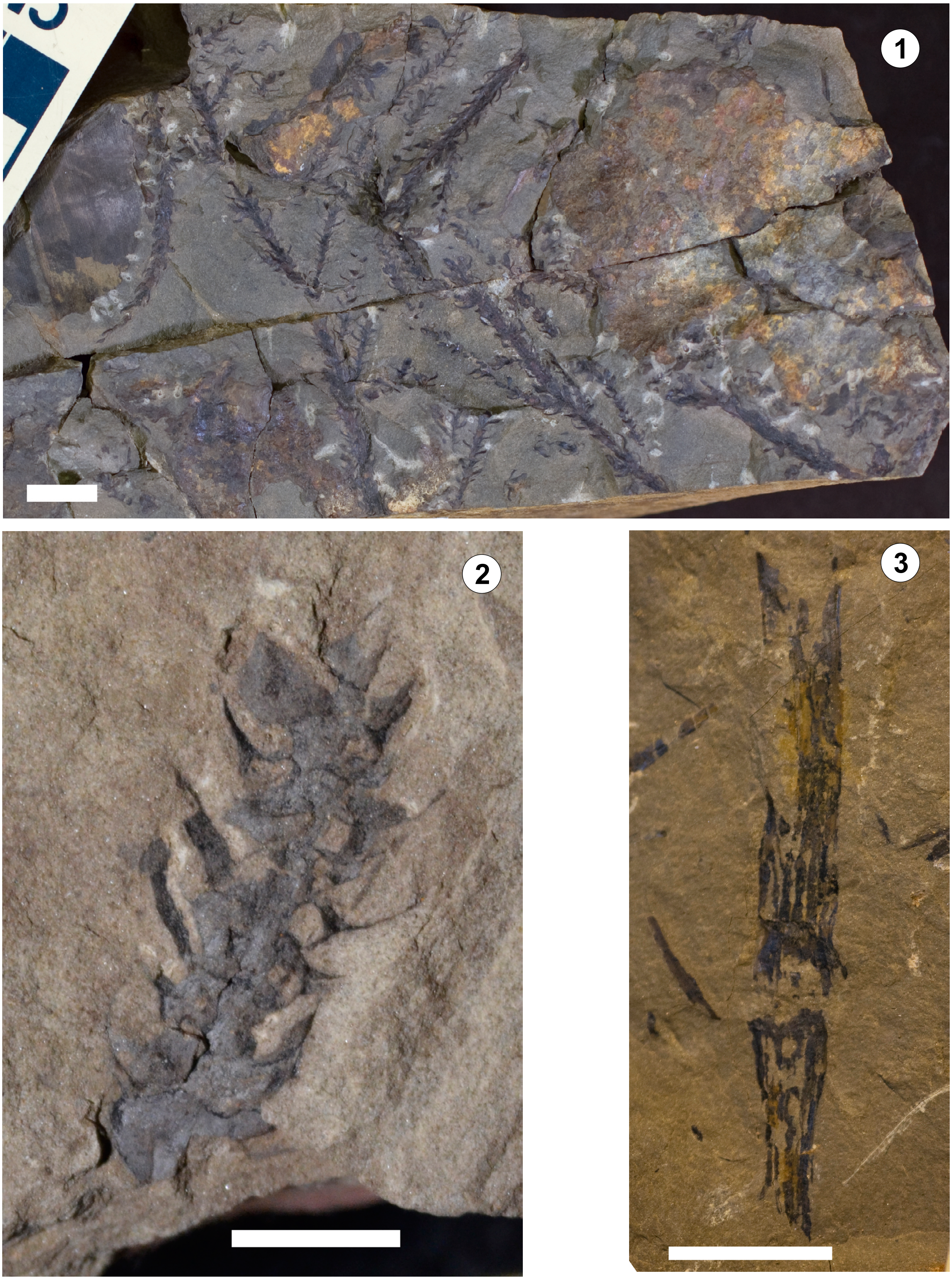

Plate I scale bars = 1 cm

1. *Lycopodites* sp., (KHFM-210020), Loc. Karamatsu-rindo-minamishisen 3,

2. *Lycopodites* sp. (KHFM-210040), Loc. Kayanokibashi, 3. *Equisetites* sp. (SDS'05-619), Loc. Shidazawaike

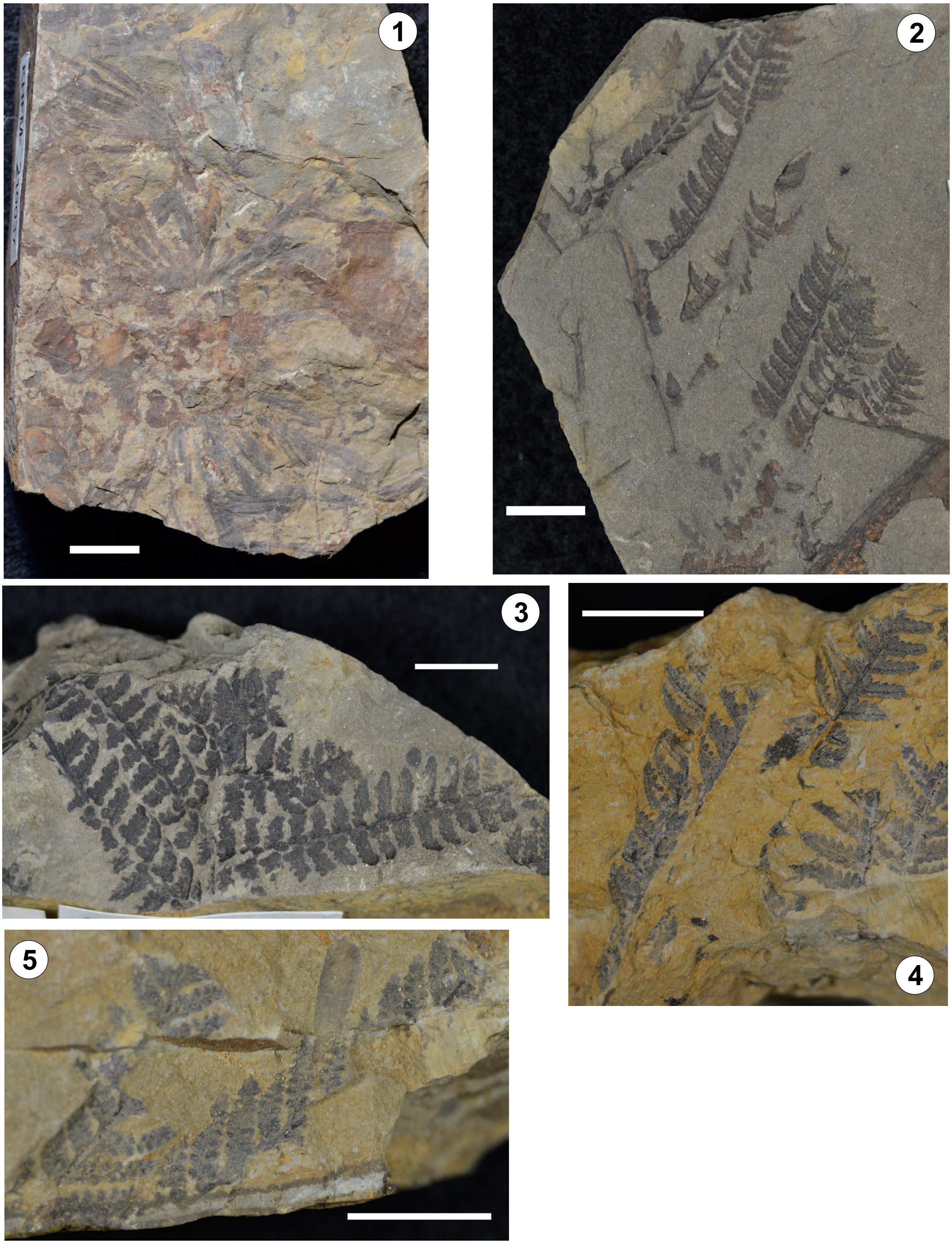

Plate II scale bars = 1 cm

1. *Neocalamites* sp., (KHFM-210037), Loc. Karamatsu-rindo minamishisen 1,

2. *Gleichenites* sp. (NSM PP-8146), Loc. Shidazawa, 3. *Gleichenites* sp. (NSM PP-8147), Loc. Shidazawa,

4. *Gleichenites* sp. (NSM PP-8151), Loc. Bunasaka, 5. *Gleichenites* sp. (NSM PP-8153), Loc. Bunasaka,

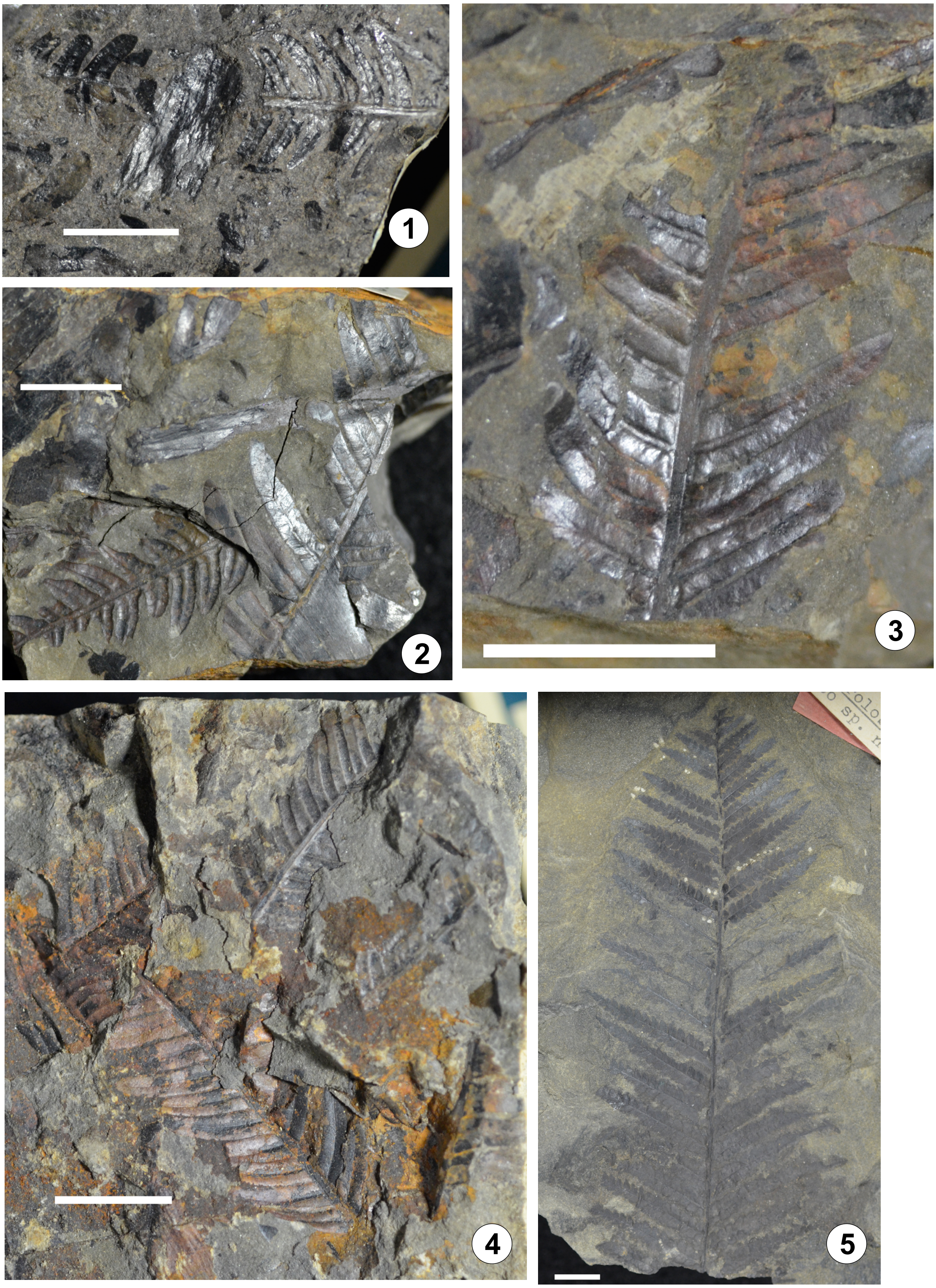

Plate III scale bars = 1 cm

1. *Matonidium* ex gr. *goepperti* (NSM PP-8163), Loc. Shidazawa, 2. *Matonidium* ex gr. *goepperti* (NSM PP-8165), Loc. Shidazawa, 3. *Matonidium* ex gr. *goepperti* (NSM PP-8166), Loc. Shidazawa, 4. *Matonidium* ex gr. *goepperti* (NSM PP-8169), Loc. Shidazawa, 5. *Eboracia microloblfolia* (NSM PP-8189), Loc. Aratozawa.

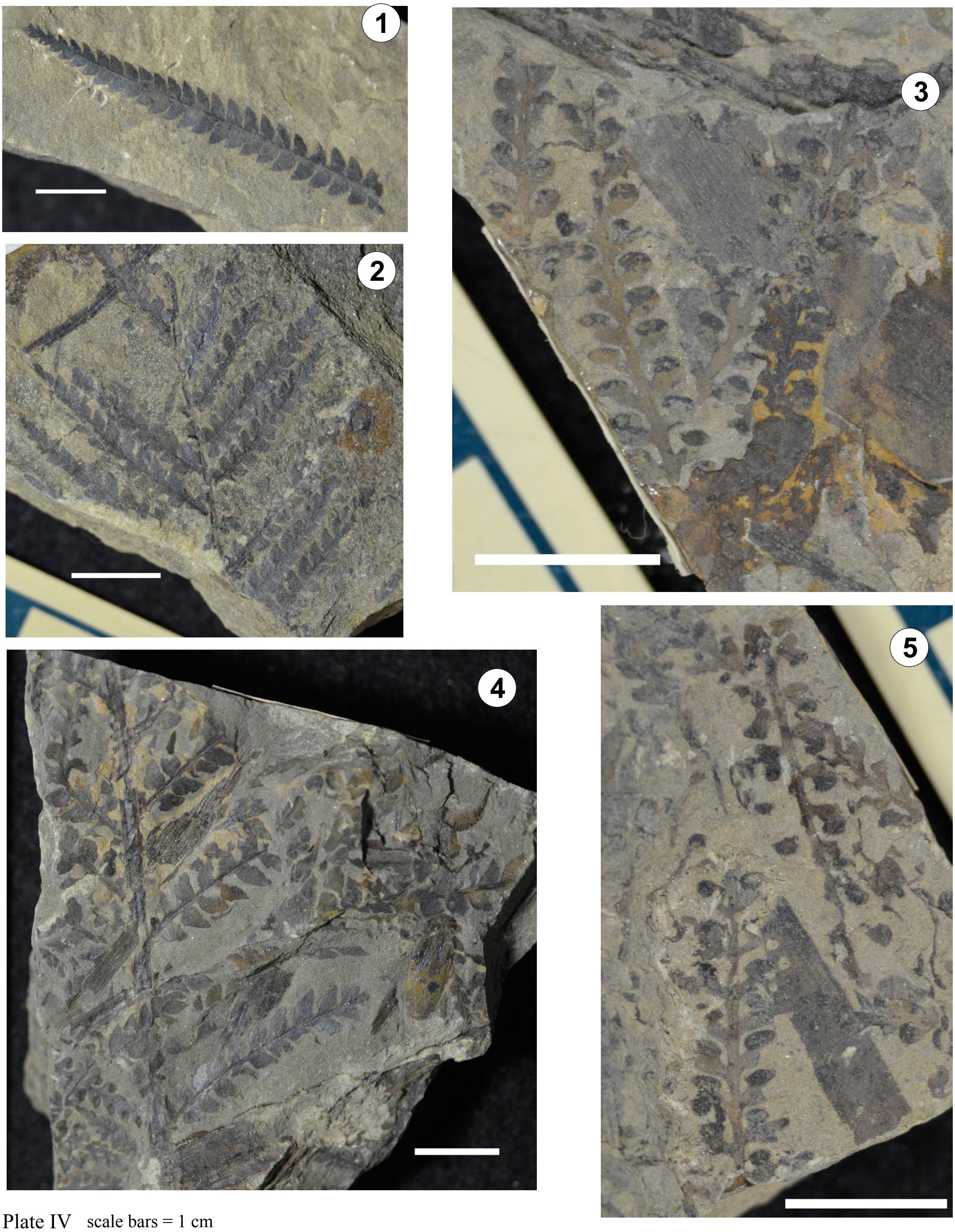

Plate IV scale bars = 1 cm

1. *Eboracia microloblfolia, sterile leaf-fragments,* (NSM PP-8170), Loc. Aratozawa, 2. *Eboracia microloblfolia* (NSM PP-8174), Loc. Aratozawa, 3. *Eboracia microloblfolia* fertile leaf-fragments, (NSM PP-8180), Loc. Bunasaka, 4. *Eboracia microloblfolia* (NSM PP-8177), Loc. Bunasaka, 5. *Eboracia microloblfolia* fertile leaf-fragments, (NSM PP-8173), Loc. Aratozawa,

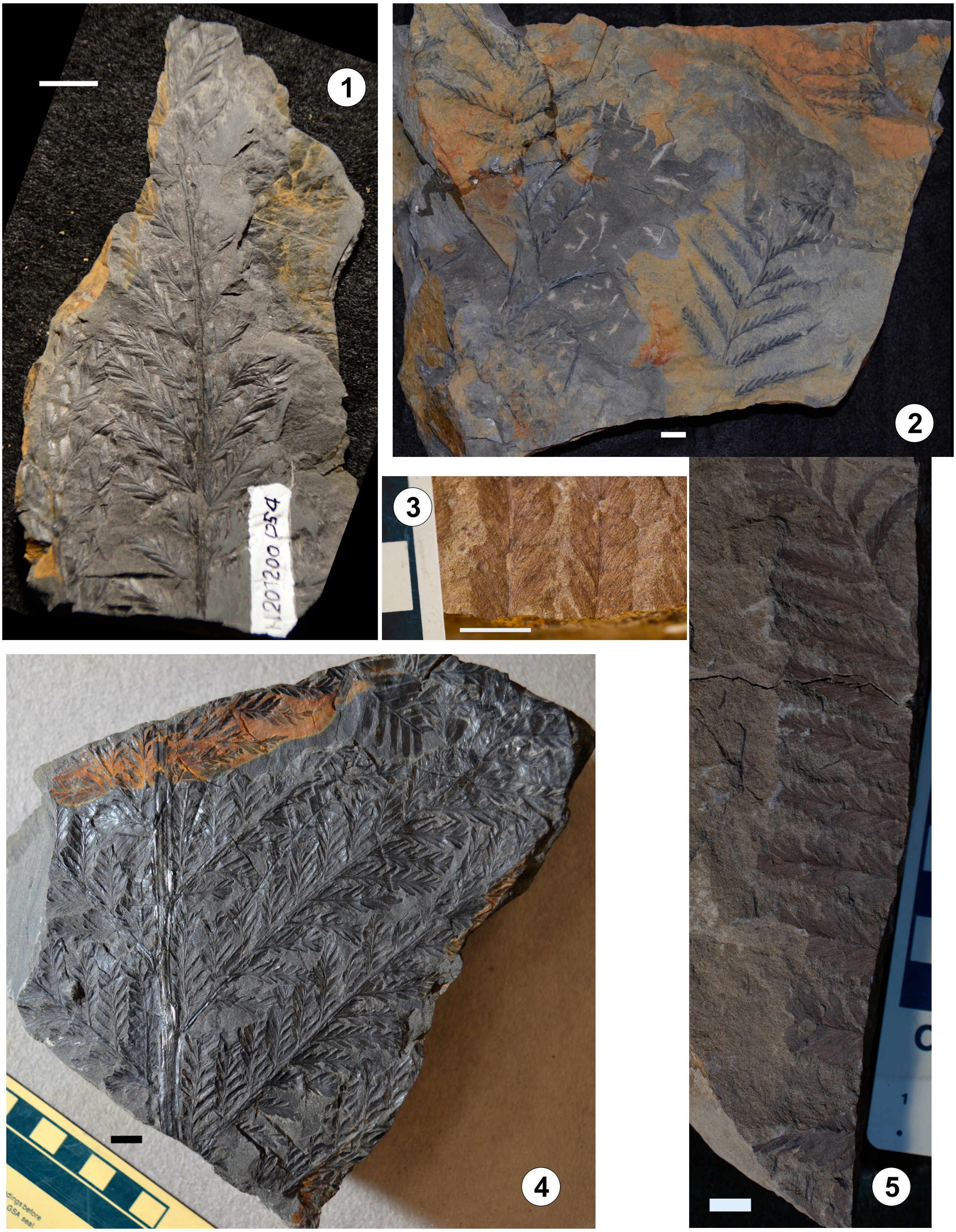

Plate V scale bars = 1 cm

1. *Onychiopsis yokoyamai* , (N201200054), Loc. Shidazawa, 2. *Onychiopsis yokoyamai* , (Ara-1), Loc. Oyama, 3. *Onychiopsis yokoyamai* , (SDS'05-779), Loc. Shidazawaike, 4. *Onychiopsis* sp. cf. *O. elongata* , (N201200016), Loc. Shidazawa, 5. *Onychiopsis yokoyamai* , (SDS'05-779), Loc. Shidazawaike,

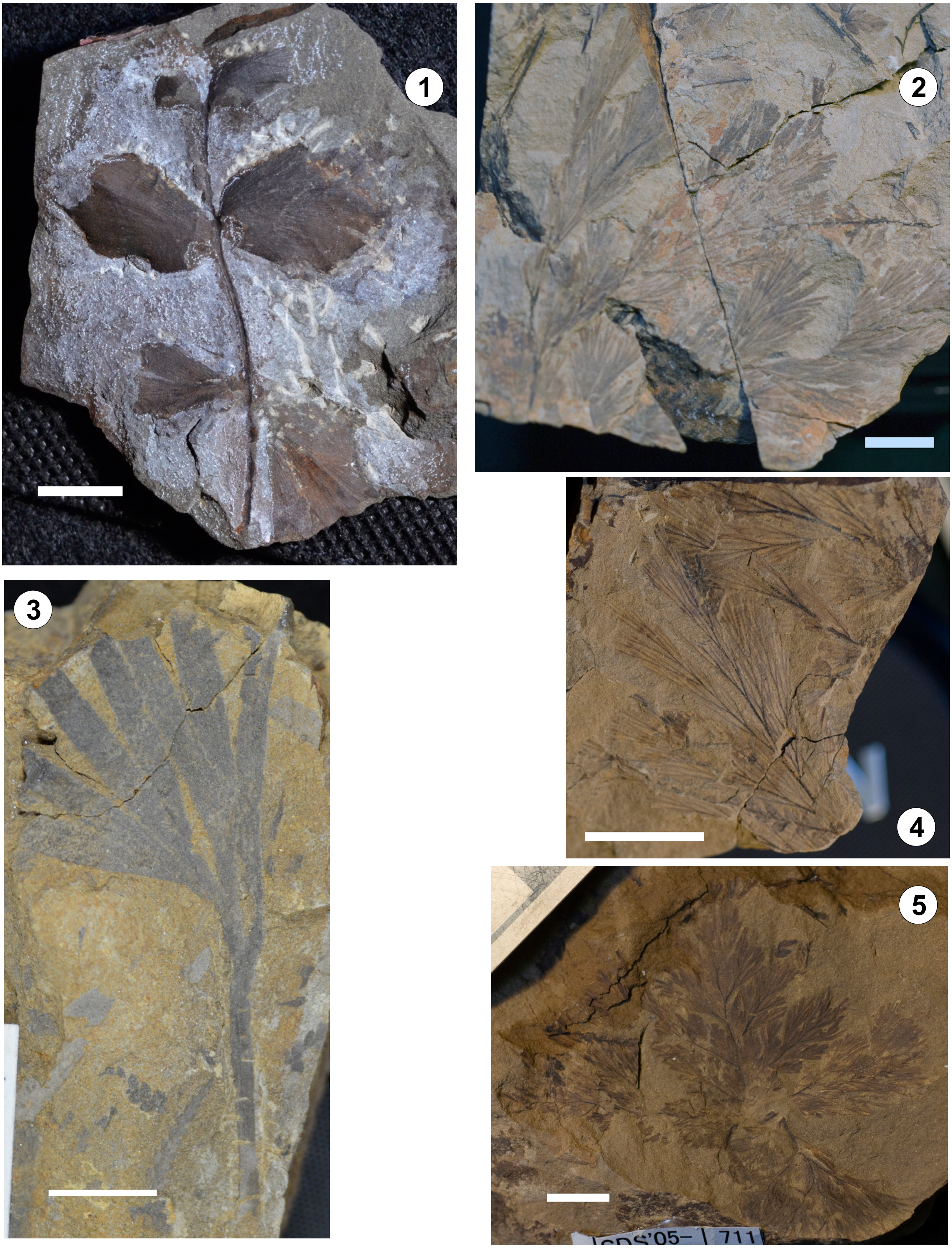

Plate VI scale bars = 1 cm

1. *Adiantopteris sp.,* (KHFM-210022), Loc. Jizomae, 2. *Acrostichopteris* sp.*,* (SDS'05-50), Loc. Shidazawaike, 3. *Acrostichopteris*? sp.*, ,* (NSM PP-8240), Loc. Bunasaka, 4. *Acrostichopteris* sp.*,* (SDS'05-56), Loc. Shidazawaike, 5. *Acrostichopteris* sp.*,* (SDS'05-711), Loc. Shidazawaike.

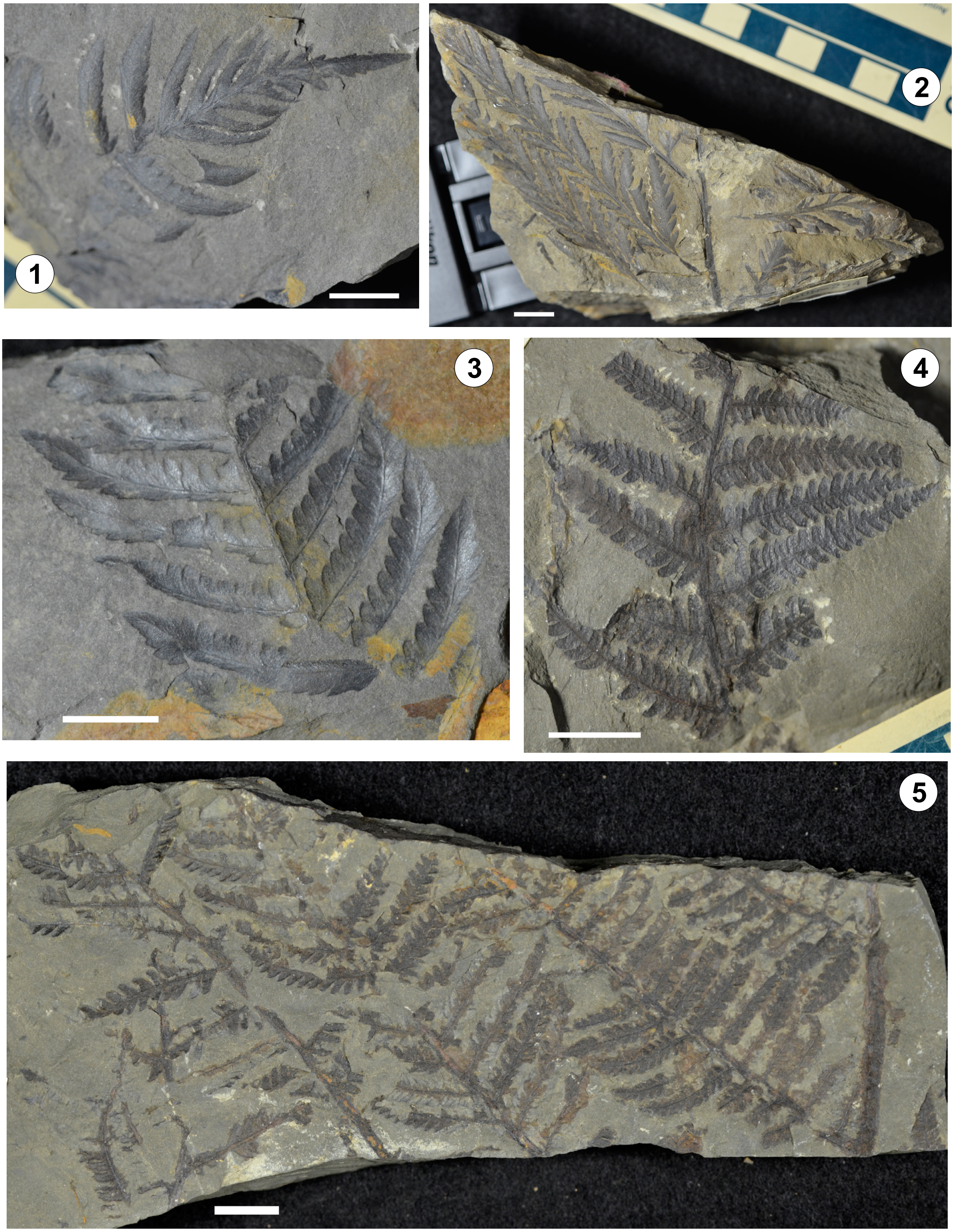

Plate VII scale bars = 1 cm

1. *Cladophlebis acutipennis,* (NSM PP-8201), Loc. Aratozawa, 2. *Cladophlebis acutipennis,* (NSM PP-8202), Loc. Aratozawa, 3. *Cladophlebis acutipennis,* (NSM PP-8203), Loc. Bunasaka, 4. *Cladophlebis matonioides,* (NSM PP-8211), Loc. Aratozawa, 5. *Cladophlebis matonioides,* (NSM PP-8208), Loc. Aratozawa.

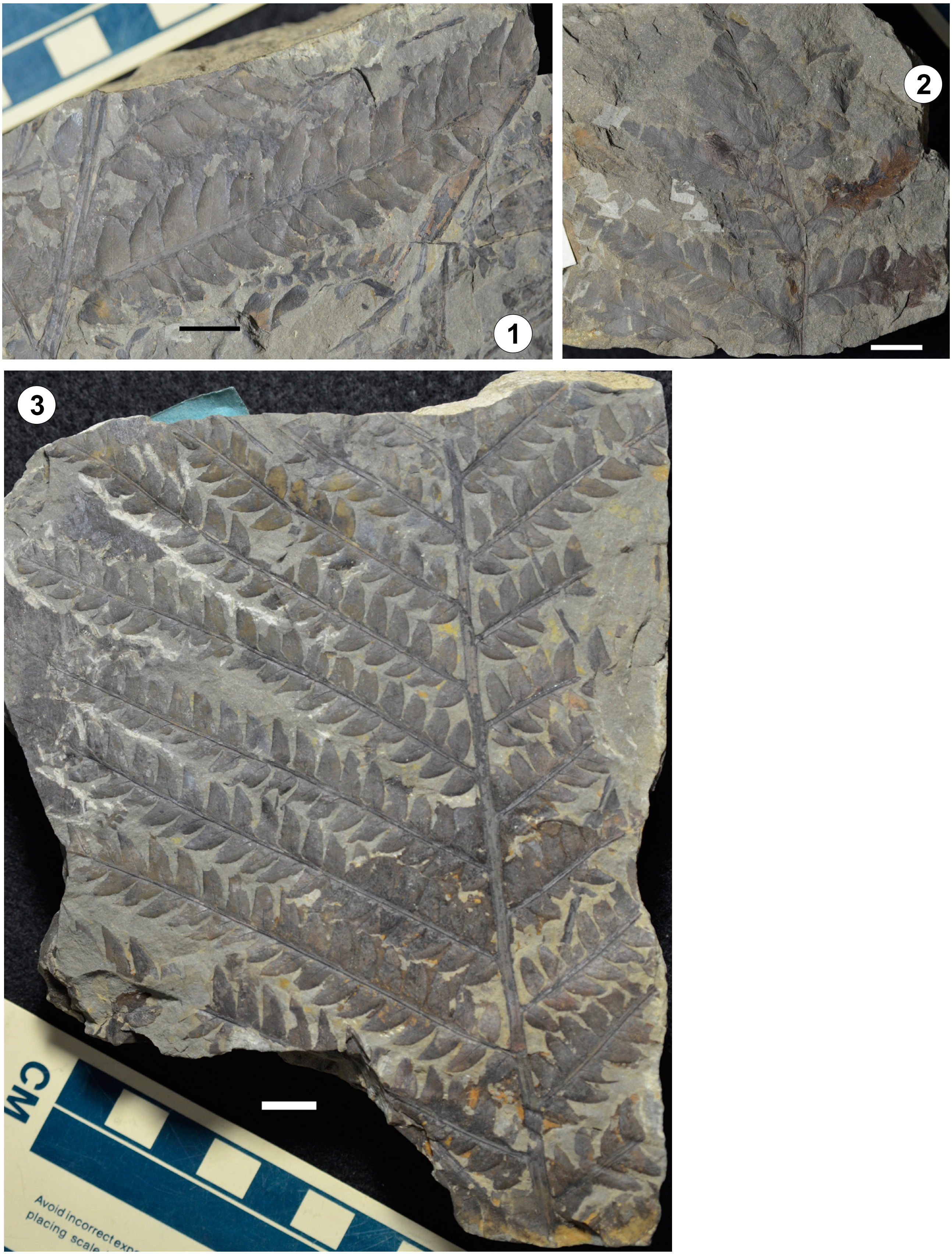

Plate VIII scale bars = 1 cm

1. *Cladophlebis* sp. cf. *C. virginiennis,* (NSM PP-8229), Loc. Aratozawa, 2. *Cladophlebis* sp. cf. *C. virginiennis,* (NSM PP-8212), Loc. Bunasaka, 3. *Cladophlebis* sp. cf. *C. virginiennis,* (NSM PP-8228), Loc. Aratozawa,

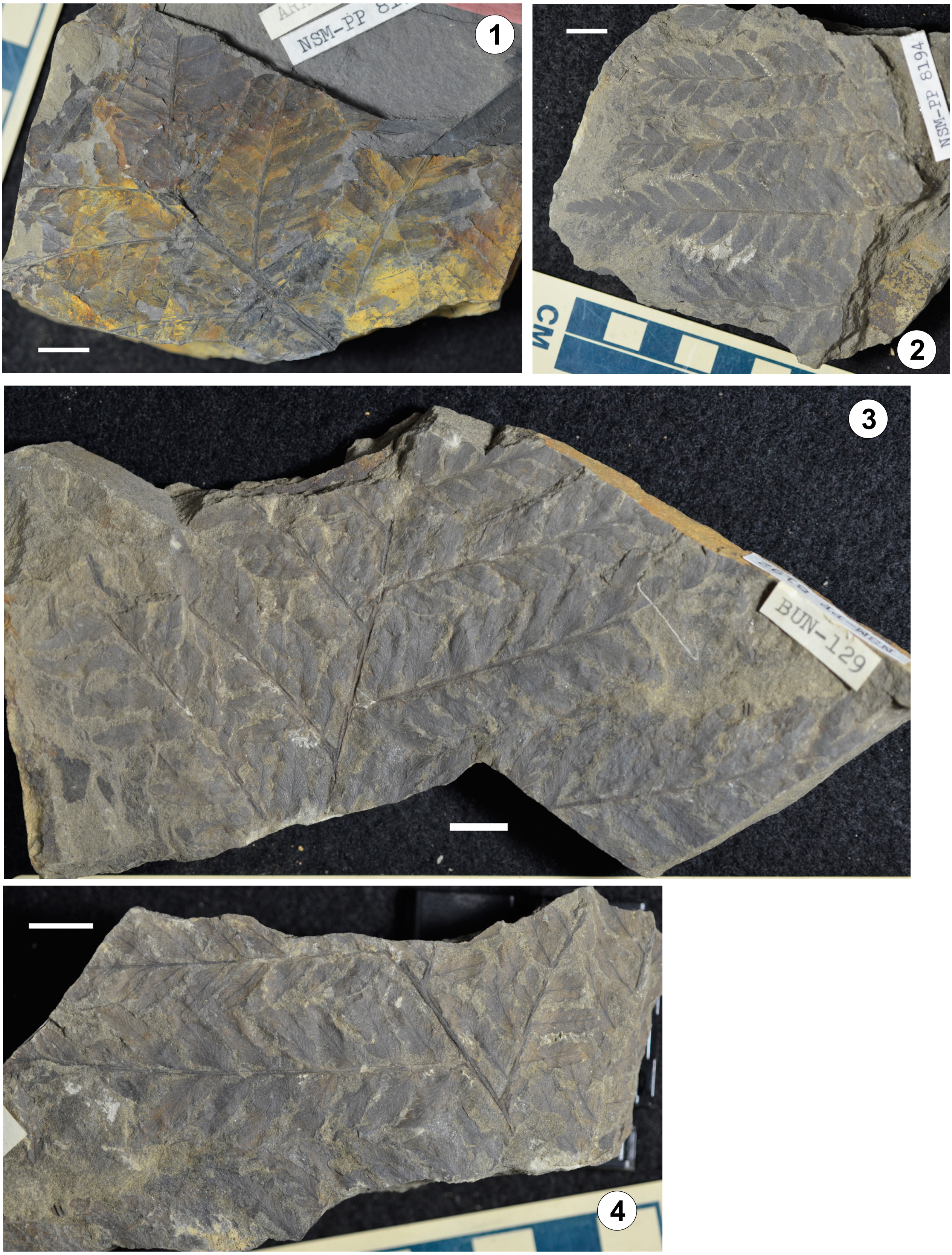

Plate IX　scale bars = 1 cm

1. *Sphenopteris elegans,* (NSM PP-8191), Loc. Aratozawa, 2. *Sphenopteris elegans,* (NSM PP-8194), Loc. Bunasaka, 3. *Sphenopteris elegans,* (NSM PP-8192), Loc. Bunasaka, 4. *Sphenopteris elegans,* (NSM PP-8196), Loc. Bunasaka

Plate X scale bars = 1 cm

1. *Otozamites* sp. cf. *O. kondoi,* (NSM PP-8242), Loc. Fukanonakayama rindo, 2. *Otozamites* sp. cf. *O. kondoi,* (N201200296), Loc. Shidazawaike, 3. *Zamites brevipennis,* (KHFM-210023), Loc. Kitanoiri,4. *Zamites nipponicus,* (NSM PP-8245), Loc. Bunasaka.

Plate XI scale bars = 1 cm

1. *Zamites nipponicus,* (NSM PP-8246), Loc. Bunasaka, 2. *Zamites nipponicus,* (NSDS-37), Loc. Shidazawakita, 3. *Zamites brevipennis,* (NSM PP-8294), Loc. Shidazawaike.

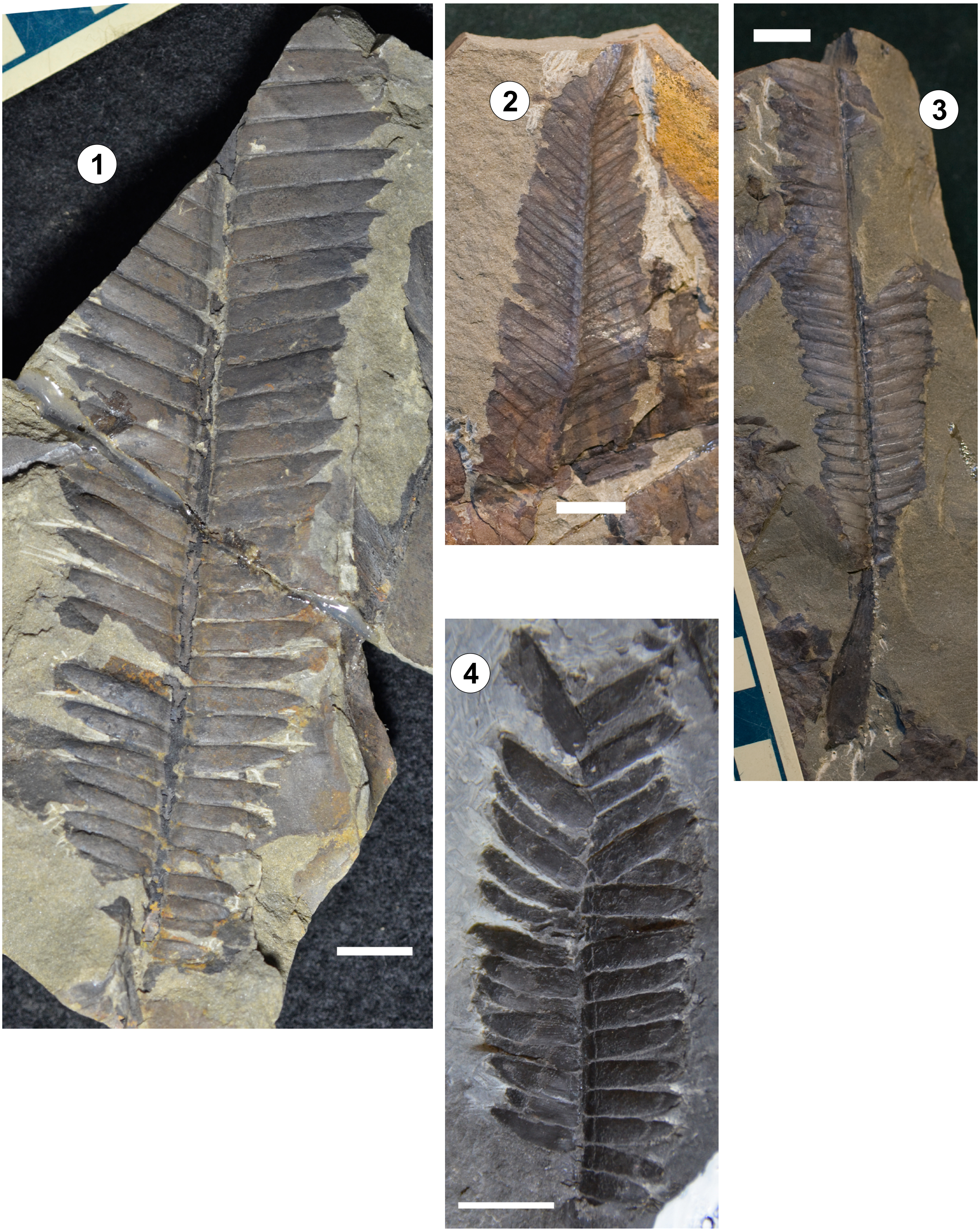

Plate XII scale bars = 1 cm

1. *Ptilophyllum jurassicum,* (NSM PP-8259), Loc. Shidazawaike, 2. *Ptilophyllum jurassicum,* leaf top, (SDS'05-342), Loc. Shidazawaike, 3. *Ptilophyllum jurassicum,* leaf base and petiole, (SDS'05-44), Loc. 4. *Ptilophyllum* sp. G, (N201200237), Loc. Shidazawa.

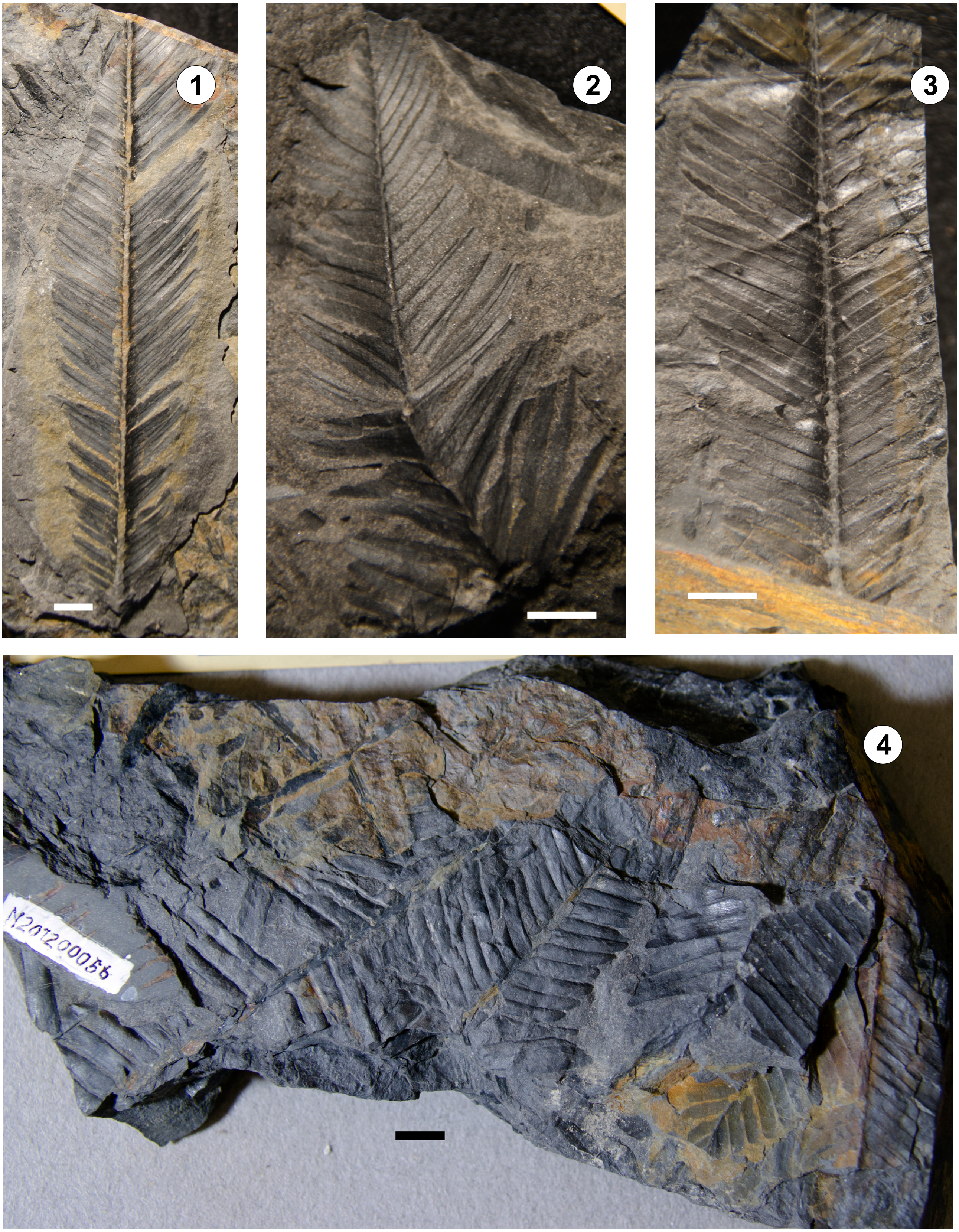

Plate XIII scale bars = 1 cm

1. *Ptilophyllum linearifolium,* (N201200096), Loc. Shidazawaike, 2. *Ptilophyllum linearifolium,* (N201200025), Loc. Shidazawaike, 3. *Ptilophyllum linearifolium,* (N201200061), Loc. Shidazawaike, 4. *Ptilophyllum oshimaense,* (N201200056), Loc. Shidazawaike.

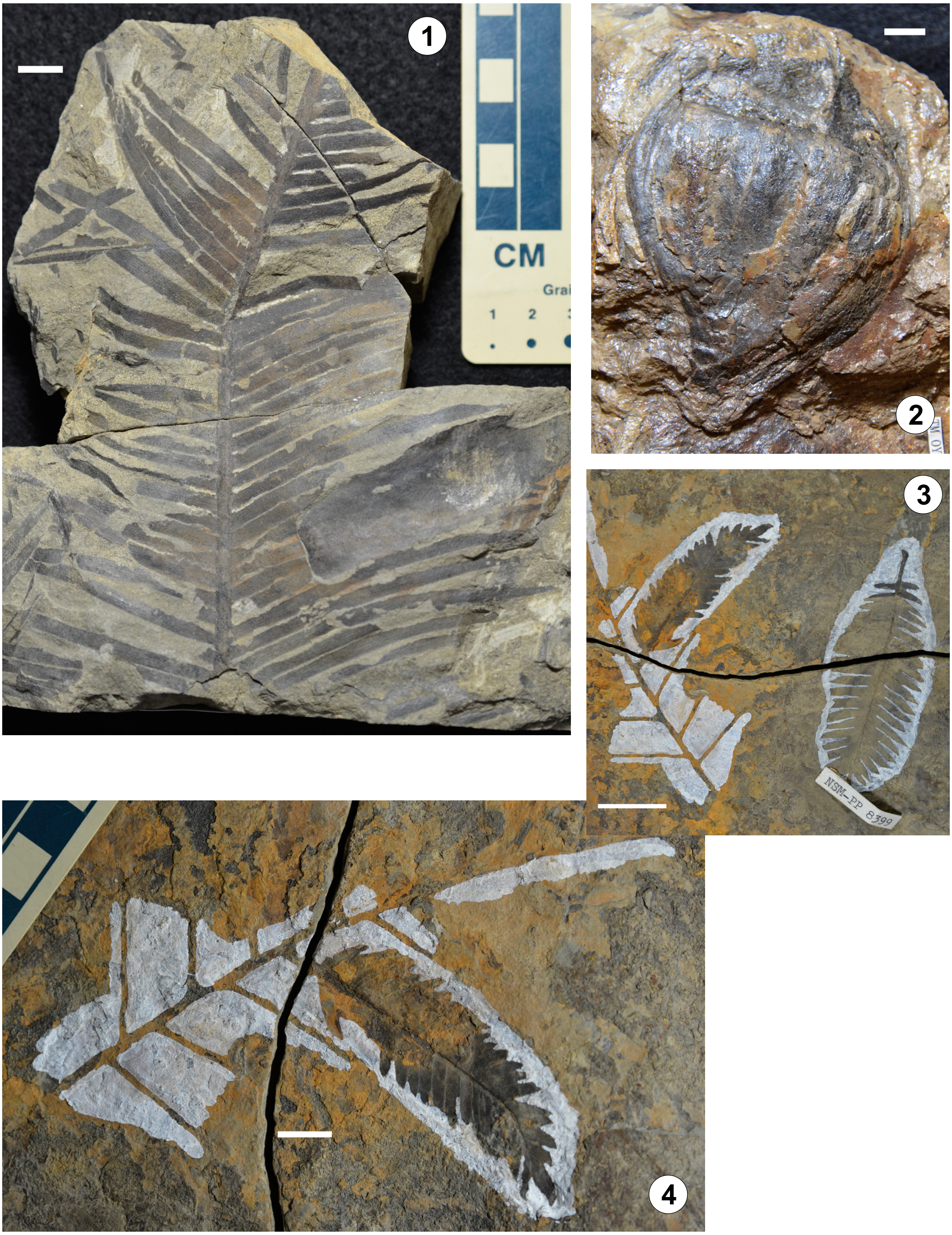

Plate XIV scale bars = 1 cm

1. *Ptilophyllum* sp F., (NSM PP-8286), Loc. Aratozawa, 2. *Williamsonia* sp., (KHFM-210025), Loc. Oyama,

3. *Nipponoptilophyllum bipinnatum,* (NSM PP-8404), Loc. Aratozawa,

4. *Nipponoptilophyllum bipinnatum,* Holotype (NSM PP-8399), Loc. Aratozawa.

Plate XV scale bars = 1 cm

1. *Pseudoctenis* sp., (NSM PP-8296), Loc. Aratozawa, 2. *Nilssonia* sp. cf. N. *canadensis,* (SDS'05-543), Loc. Shidazawaike, 3. *Nilssonisa* sp. cf. N. *densinervis,* (NSM PP-8309), Loc. Aratozawa, 4. *Nilssonisa* sp. cf. N. *densinervis,* (NSM PP-8310), Loc. Aratozawa, 5. *Nilssonisa longipinnata,* (NSM PP-8311), Loc. Aratozawa.

Plate XVI scale bars = 1 cm

1. *Nilssonia oblique-truncata,* (NSM PP-8320), Loc. Aratozawa, 2. *Nilssonia oblique-truncata,* (NSM PP-8319), Loc. Aratozawa, 3. *Nilssonia* ex gr. *schaumburgensis,* (NSM PP-8340), Loc. Aratozawa.

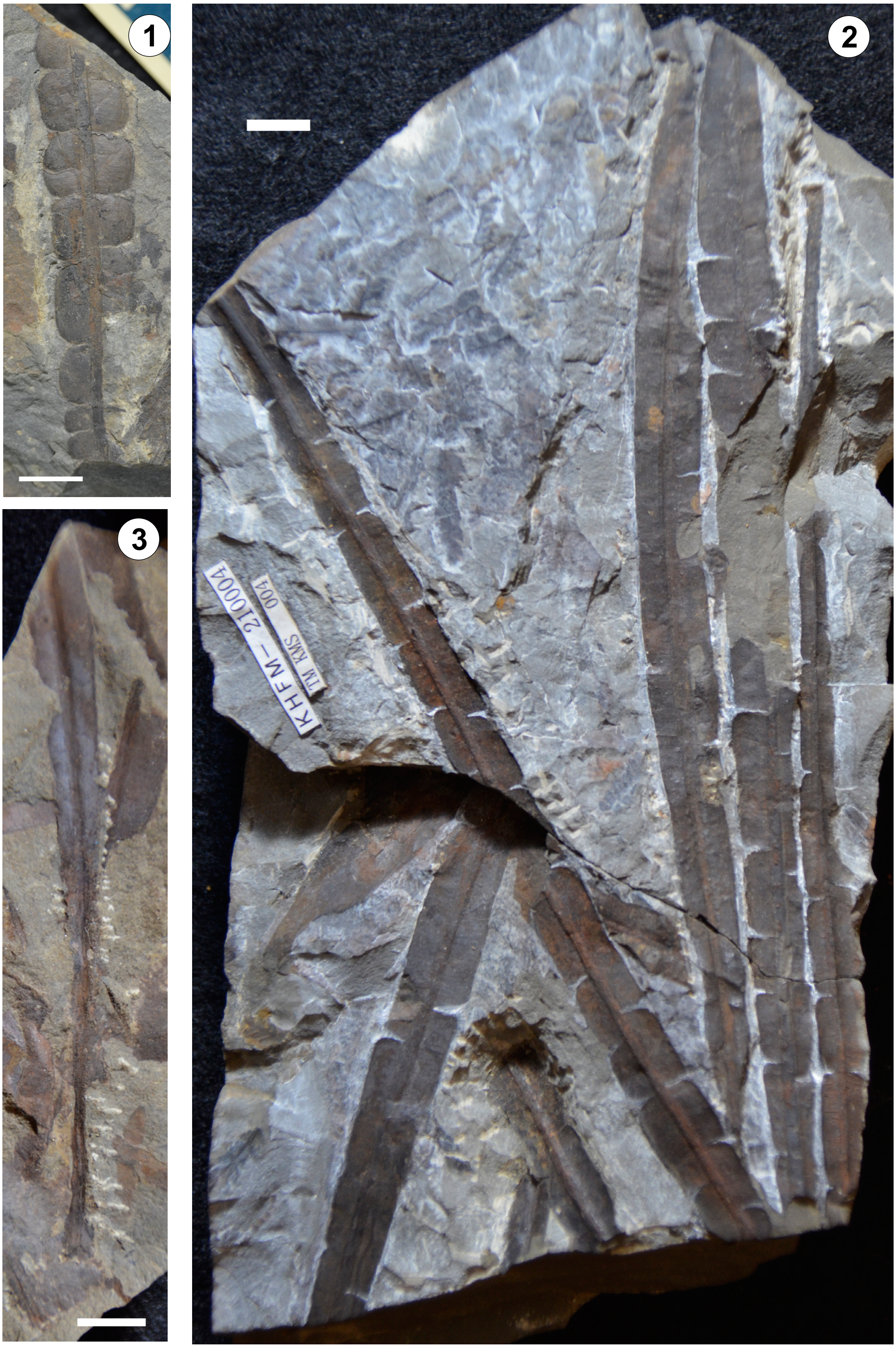

Plate XVII scale bars = 1 cm

1. *Nilssonia* ex gr. *schaumburgensis,* (NSM PP-8338), Loc. Aratozawa.

2. *Nilssonia* ex gr. *schaumburgensis,* (KHFM-210004), Loc. Karamatsurindo-minamishisen 3.

3. *Nilssonia* ex gr. *schaumburgensis,* (KHFM-210019), Loc. Karamatsurindo-minamishisen 3.

Plate XVIII scale bars = 1 cm

1. *Nilssoniocladus tairae,* Holotype (KHFM-210007), Loc. Karamatsurindo-minamishisen 3.

2. *Nilssoniocladus tairae,* leaf top, (KHFM-210011) Loc. Karamatsurindo-minamishisen 3.

3. *Nilssoniocladus tairae,* (KHFM-210011) Loc. Karamatsurindo-minamishisen 3.

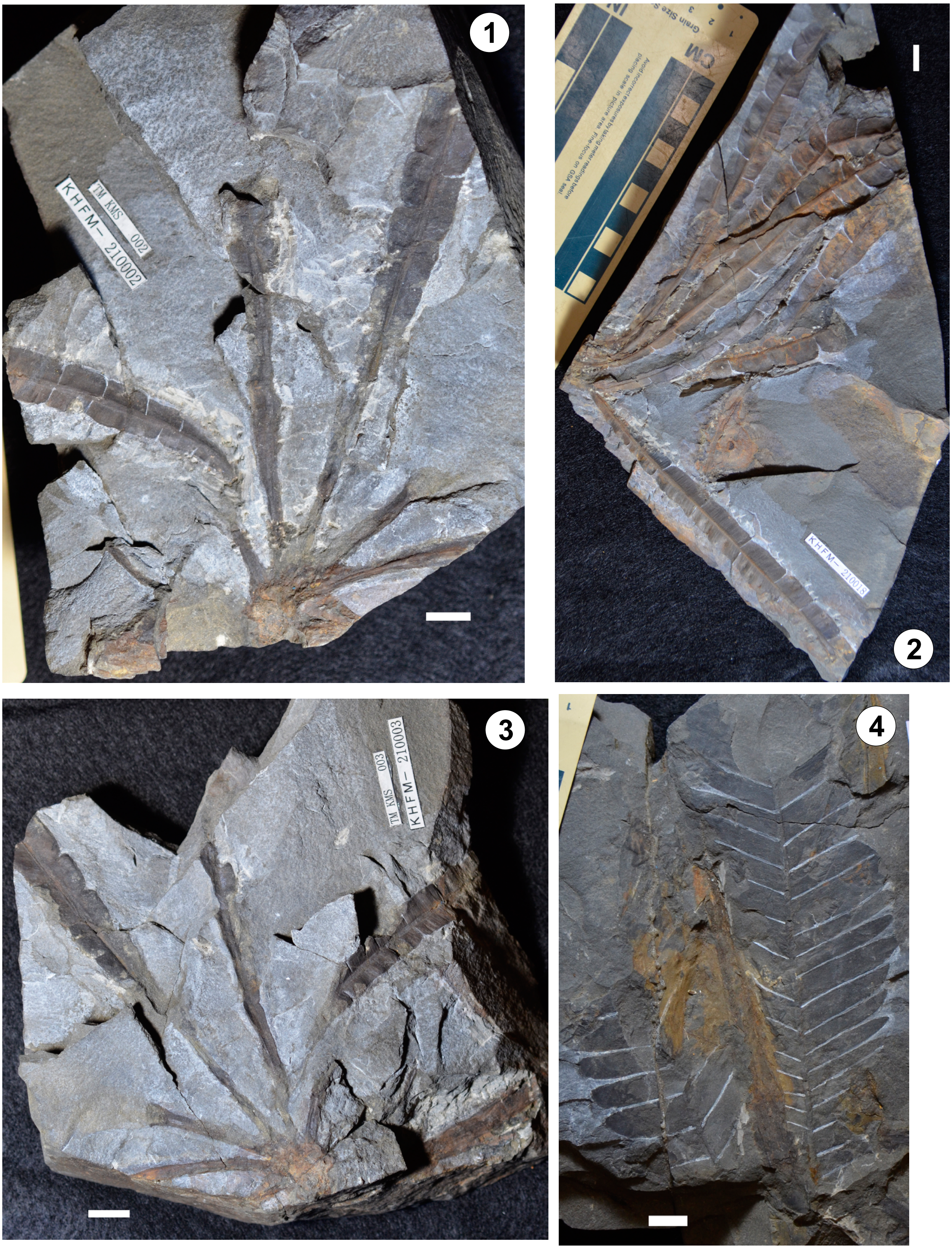

Plate XIX scale bars = 1 cm

1. *Nilssoniocladus japonicus,* Paratype (KHFM-210002), Loc. Karamatsurindo-minamishisen 3,

2. *Nilssoniocladus japonicus,* (KHFM-210018) Loc. Karamatsurindo-minamishisen 3,

3. *Nilssoniocladus japonicus,* Holotype (KHFM-210003), Loc. Karamatsurindo-minamishisen 3,

3. *Nilssoniocladus tairae,* (KHFM-210010) Loc. Karamatsurindo-minamishisen 3.

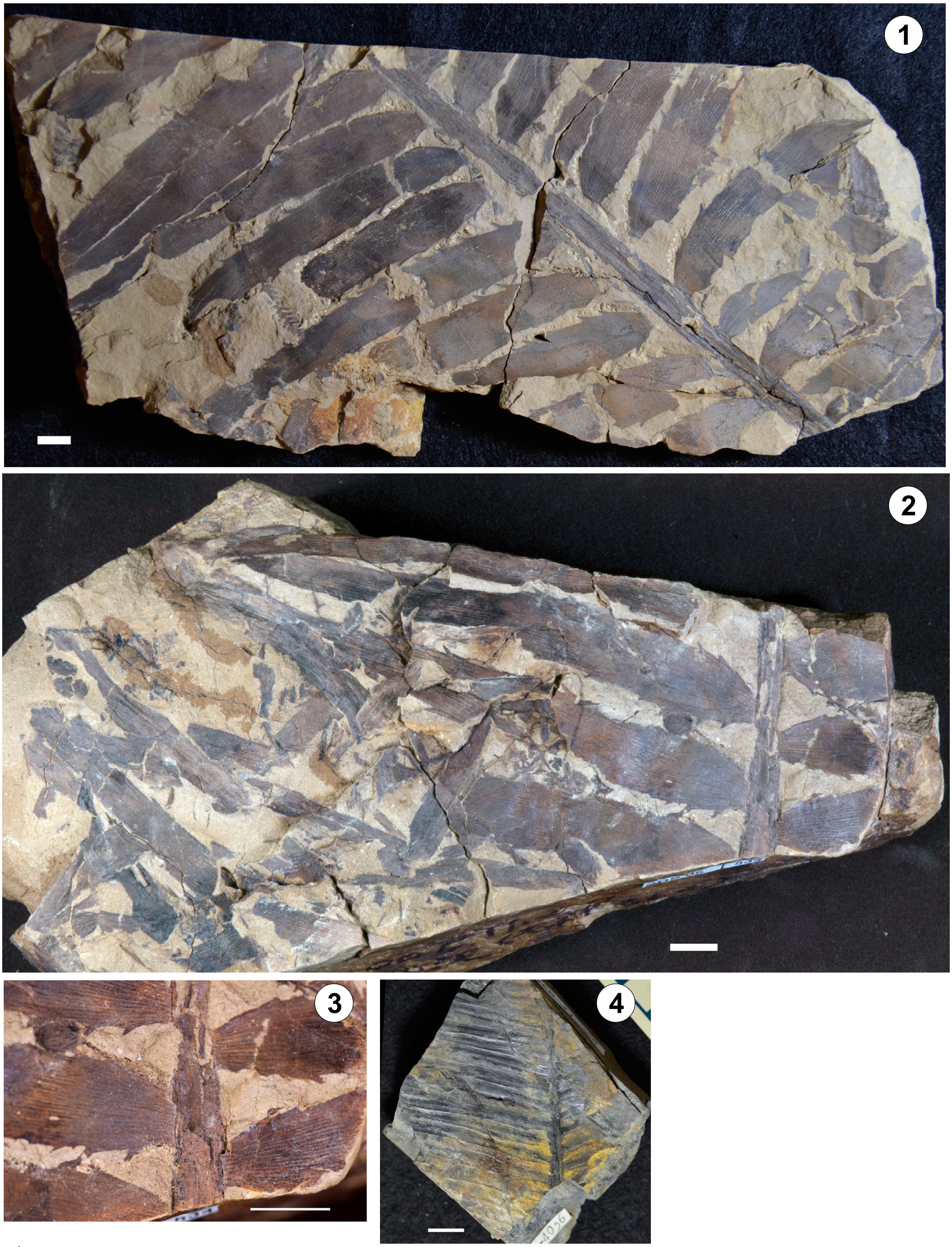

Plate XX scale bars = 1 cm

1. *Encephalartites nipponensis,* Holotype (MM-008487), Loc. Shidazawaike, 2. *Encephalartites nipponensis,* Paratype (MM-008490), Loc. Shidazawaike, 3. *Encephalartites nipponensis,* Paraype (MM-008490), Loc. Shidazawaike, 4. *Cycadites* sp, (NSM PP-8347), Loc. Bunasaka.

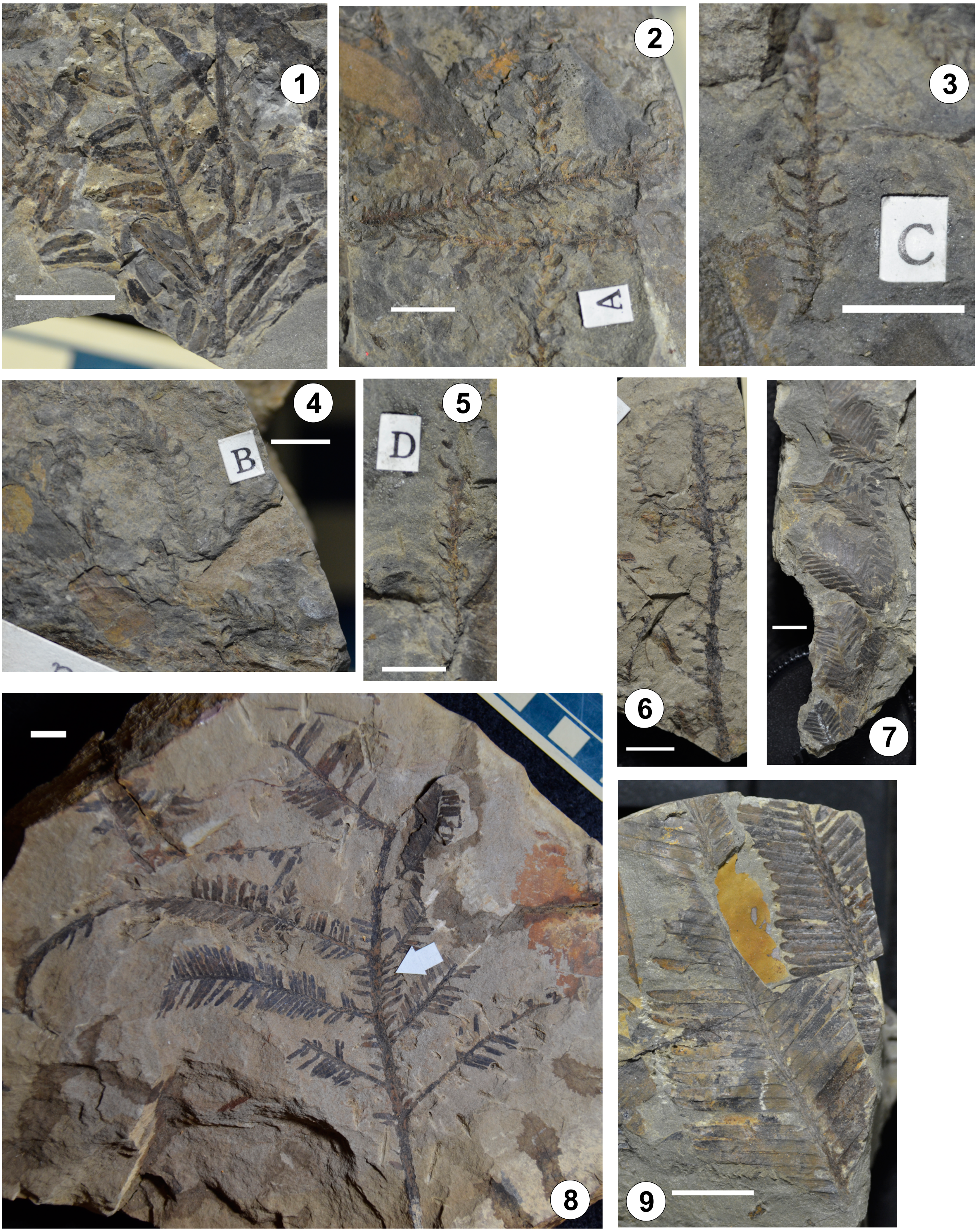

Plate XXI scale bars = 1 cm

1. *Elatocladus* sp., (NSM PP-8351), Loc. Aratozawa, 2. *Pagiophyllum* sp., (NSM PP-8373A), Loc. Umenokizawa, 3. *Pagiophyllum* sp., (NSM PP-8373C), Loc. Umenokizawa, 4. *Pagiophyllum* sp., (NSM PP-8373B), Loc. Umenokizawa,5. *Pagiophyllum* sp., (NSM PP-8373D), Loc. Umenokizawa,6. *Pagiophyllum* sp., (NSM PP-8375), Loc. Umenokizawa, 7. *Parasequoia* sp., (NSM PP-8373B), Loc. Aratozawa, 8. *Parasequoia* sp., (NSM PP-8373B), Loc. Tatenosawa, 9. *Parasequoia* sp., (NSM PP-8373B), Loc. Aratozawa.

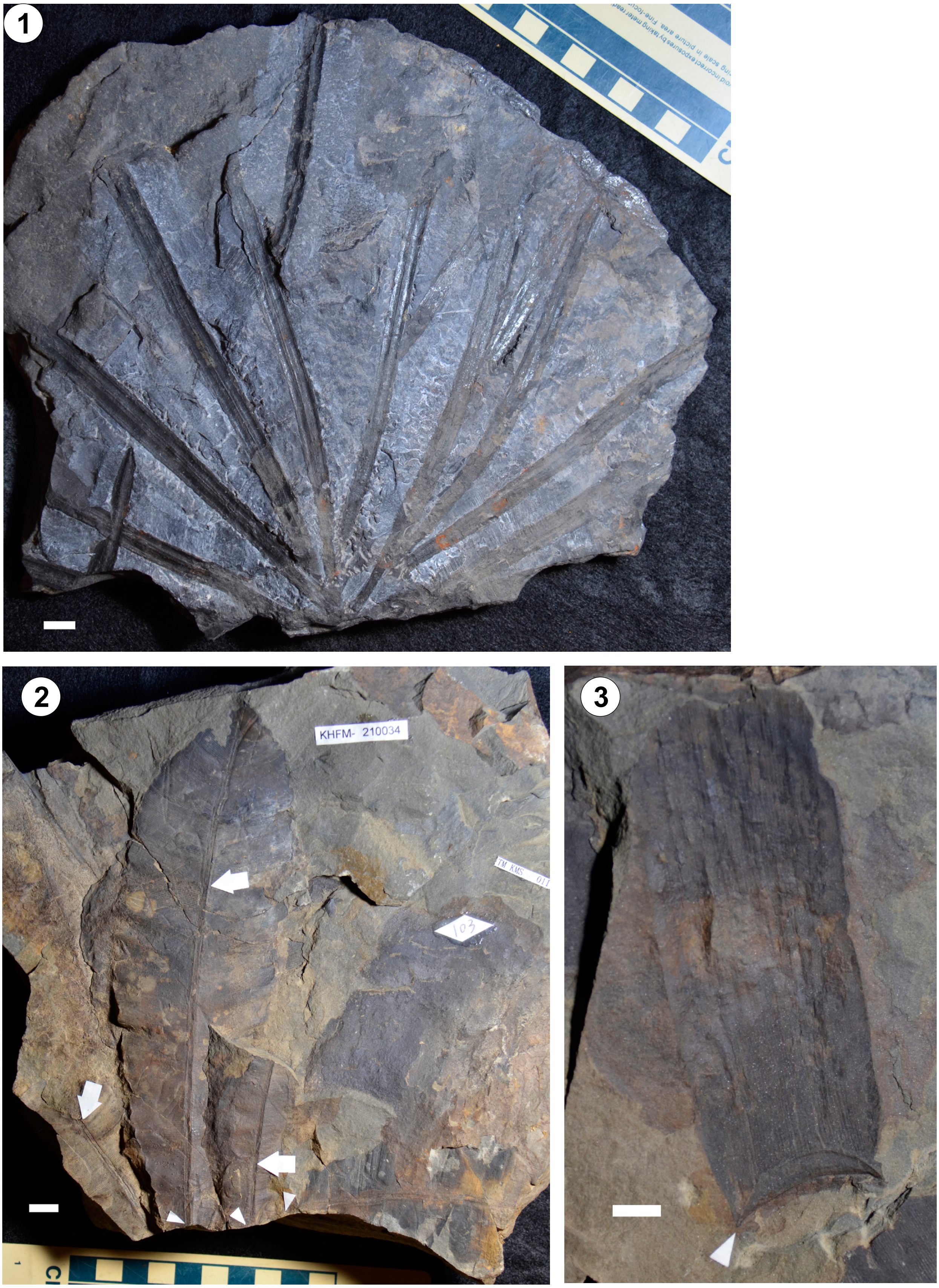

Plate XXII scale bars = 1 cm

1. *Taeniatus elongatus,* Holotype (MM-00108-376-024G), Loc. Shidazawaike, 2. *Taeniopteris somaensis,* Holotype (KHFM-210034), Loc. Tatenosawa, 3. *Pelourdea nipponica,* (KHFM-210032), Holotype, Loc. Karamatsurindo-minamishisen 2.

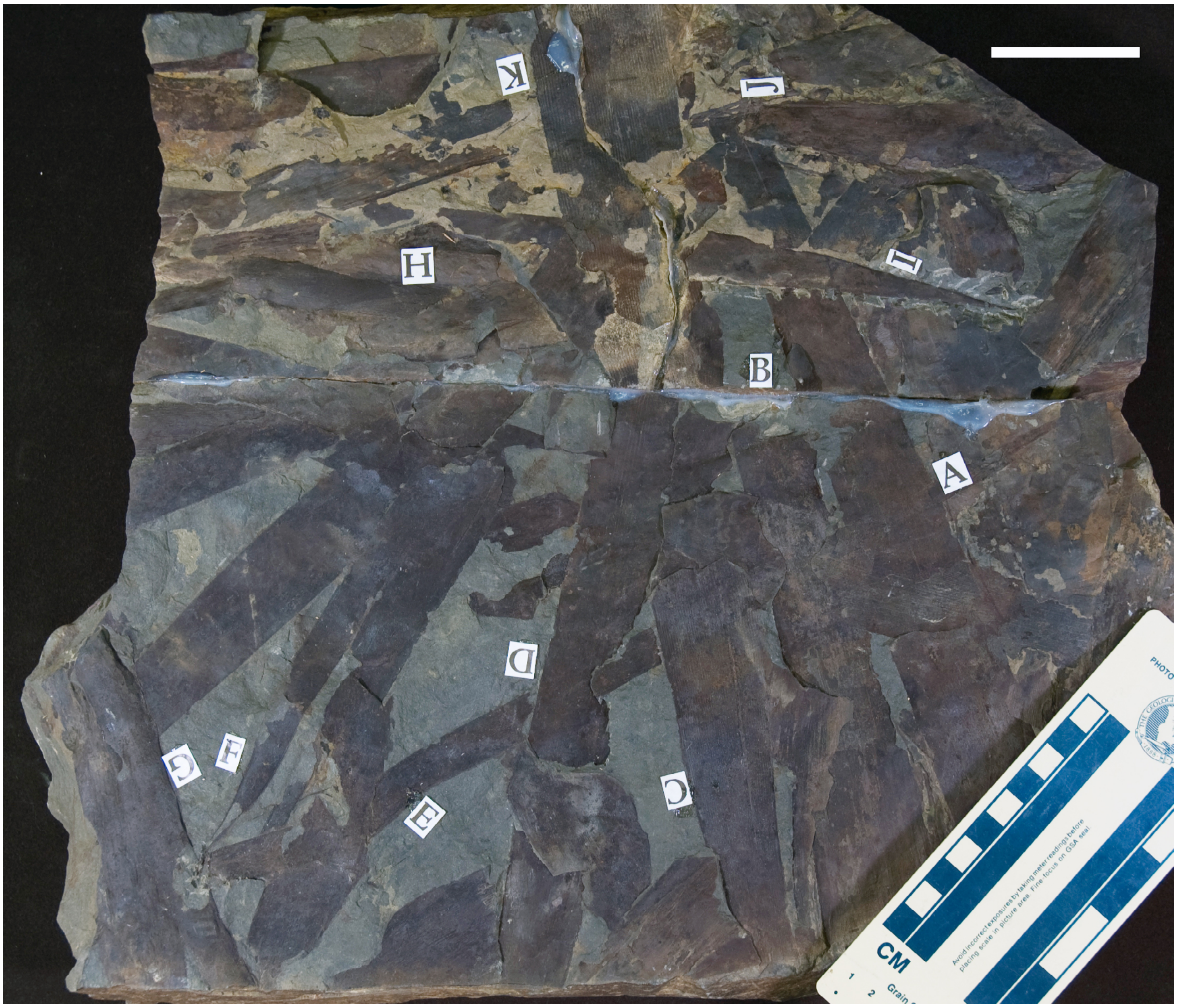

Plate XXIII

Pelourdea nipponica, (KHFM-210031)Loc. Karamatsurindo-minamishisen 2, scale bar = 5 cm.

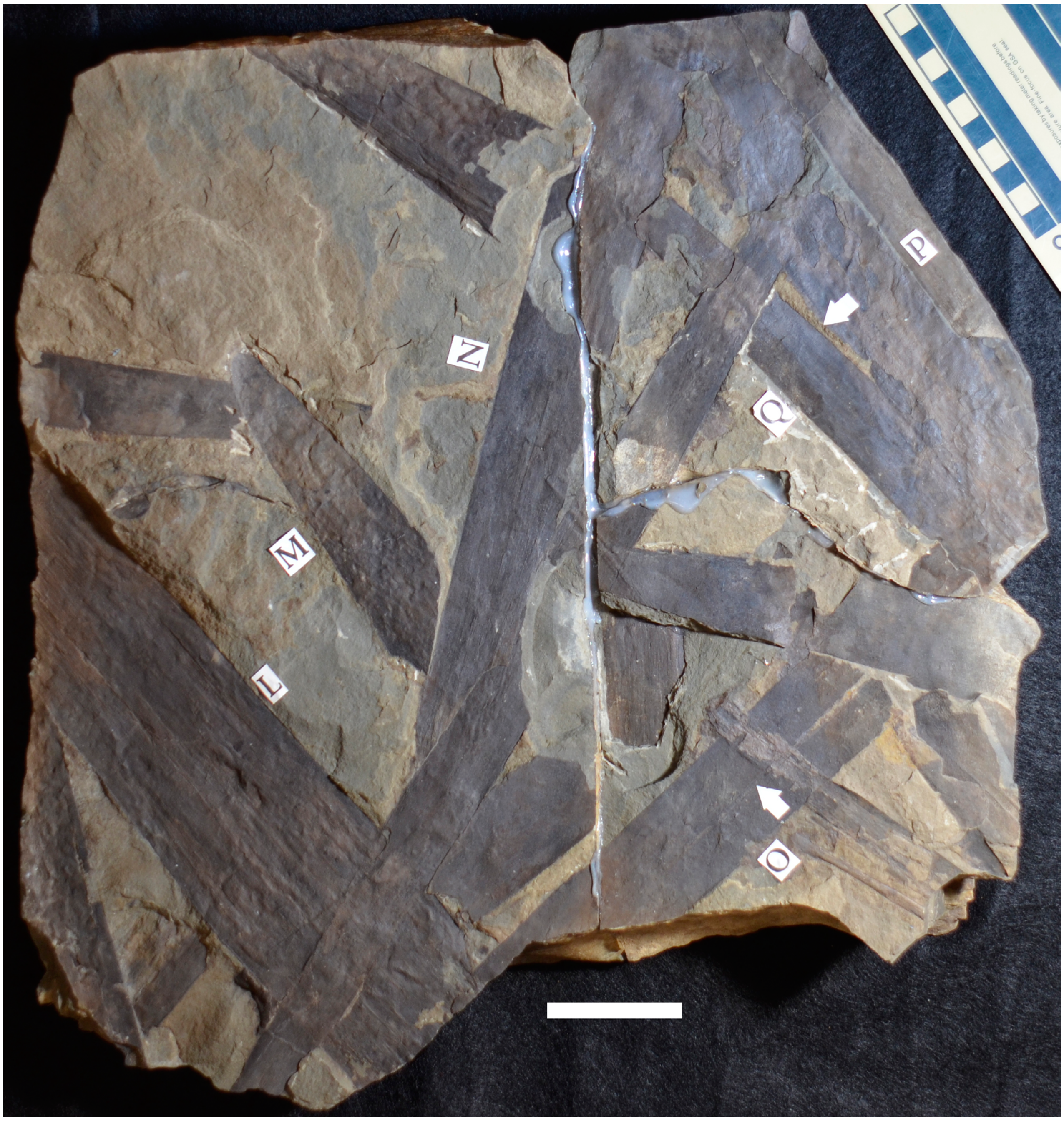

Plate XXIV

Pelourdea nipponica, (KHFM-210033), Paratype, Loc. Karamatsurindo-minamishisen 2, scale bar = 5 cm.